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WATER QUALITY MANAGEMENT

ANALYSIS OF SUMMIT COUNTY, COLORADO

U.S. Environmental Protection Agency
Region VIII
Air and Water Programs Division

and

Colorado Department of Health
Water Pollution Control Division

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WATER QUALITY MANAGEMENT ANALYSIS OF SUMMIT COUNTY, COLORADO

I. INTRODUCTION

A. Purpose

The purpose of this study is to:

1) Evaluate the impact of continued recreation development on water quality in Summit County, Colorado.

2) Define the assimilative capacity of hydrologic entities within the basin.

3) Identify and examine various wastewater treatment and disposal alternatives to meet ambient water quality standards within the basin.

4) As an alternative to wastewater treatment, examine land use controls required to reduce the amount of nutrients entering Dillon and Green Mountain Reservoirs.

5) Assess the economic feasibility, environmental impacts, and acceptability of alternative management schemes.

B. Scope

The scope of this report will be confined to examining the effects on water quality from both municipal waste and non-point waste sources and determining economically and environmentally feasible management plans. Water quality parameters pertinent to lake eutrophication will be of specific interest in this analysis.

C. Existing Water Quality Standards

The entire Blue River hydrologic basin which encompasses Summit County is classified for use as a municipal water supply, cold water fishery, and industrial and irrigation purposes. The water quality standards and criteria imposed by the State of Colorado and appli-

cable to the Blue River including Dillon and Green Mountain reservoirs are summarized in Table I.

TABLE 1. Applicable Water Quality Criteria

Class	Fecal Coliform Bacteria	D.O. (mg/l)	pH	T.D.S. (mg/l)	Temp. (°F)	Toxic Materials
A,B_1,C,D_1	<1000/100 ml	6.0	6.5-8.5	<500	≤70°	Free from materials toxic to aquatic animals and crops.

In addition, the language of the Colorado Water Quality Standards specifies that all waters of the State will be "free from materials attributable to municipal, domestic, or industrial wastes or other controllable sources that will produce objectionable odor, color, taste, or turbidity in the water, or objectional aquatic life which may result in eutrophication or other conditions that interfere with the classified use of the water."

The Summit County Board of Commissioners has adopted a resolution requiring secondary treatment followed by phosphate reduction of all sewage discharged to the waters of the county. The county standards require that any sewage treatment facility "shall remove 98% of the BOD, 99% of the suspended solids and 95% reduction of the phosphates."

D. Existing Water Quality

Existing water quality of streams and bodies of water within Summit County is generally in compliance with water quality standards. There are currently no known severe water pollution

problems within Summit County. At the present ambient nutrient levels in Dillon Reservoir, nuisance algae blooms or cultural eutrophication would not generally be expected to occur. There may be certain areas such as inlets to the reservoir where complete mixing does not occur and problems could arise. Figure 1 represents typical water quality for selected constituents in various portions of the Blue River Basin. None of the existing municipal waste discharges reliably meet the standards adopted by the County Board of Commissioners.

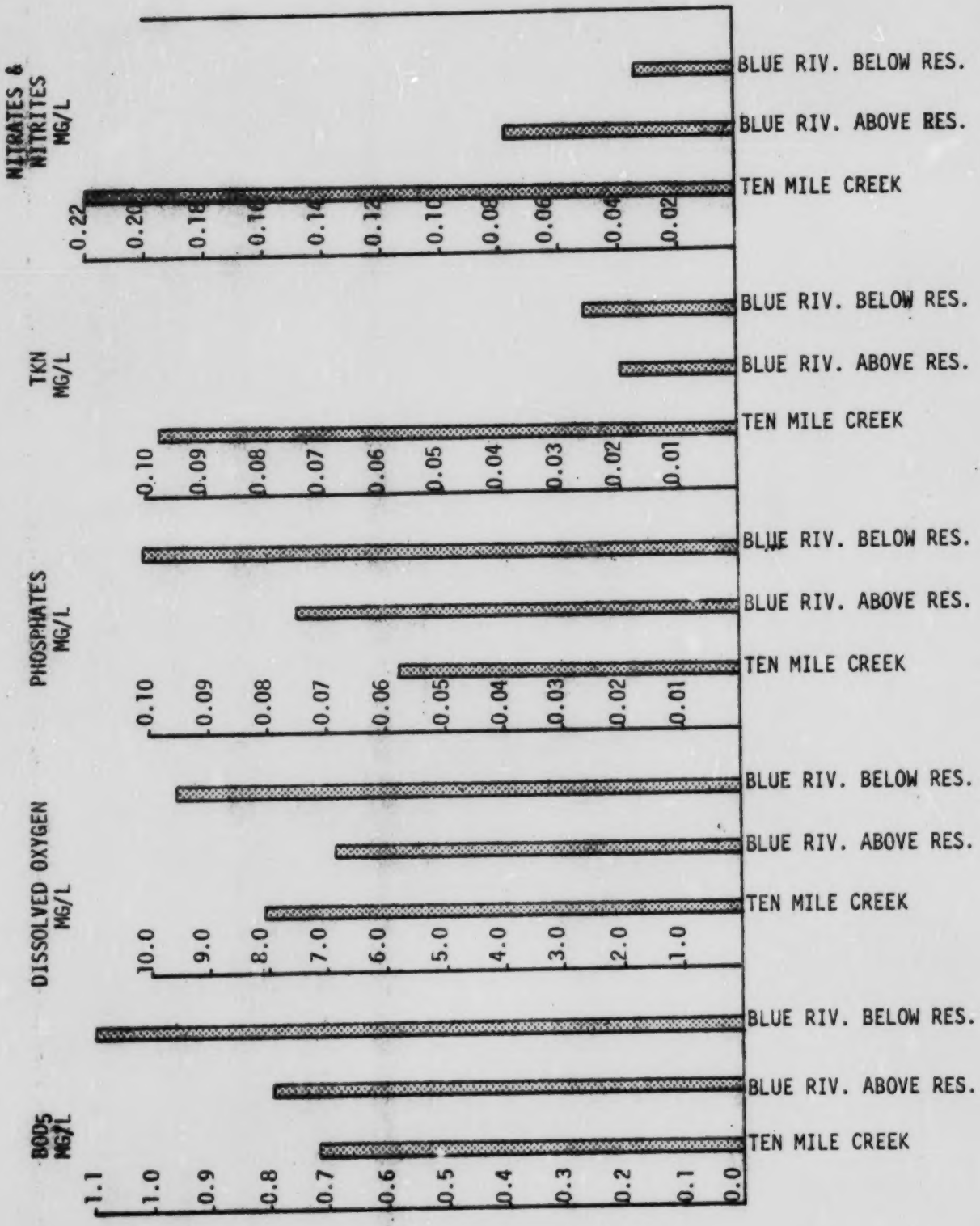


FIGURE 1

STREAM CONSTITUENTS NEAR DILLON RESERVOIR
DATA FROM COLORADO WATER POLLUTION CONTROL STREAM SAMPLES

II. BASIN CHARACTERISTICS AND PROJECTED LAND USES

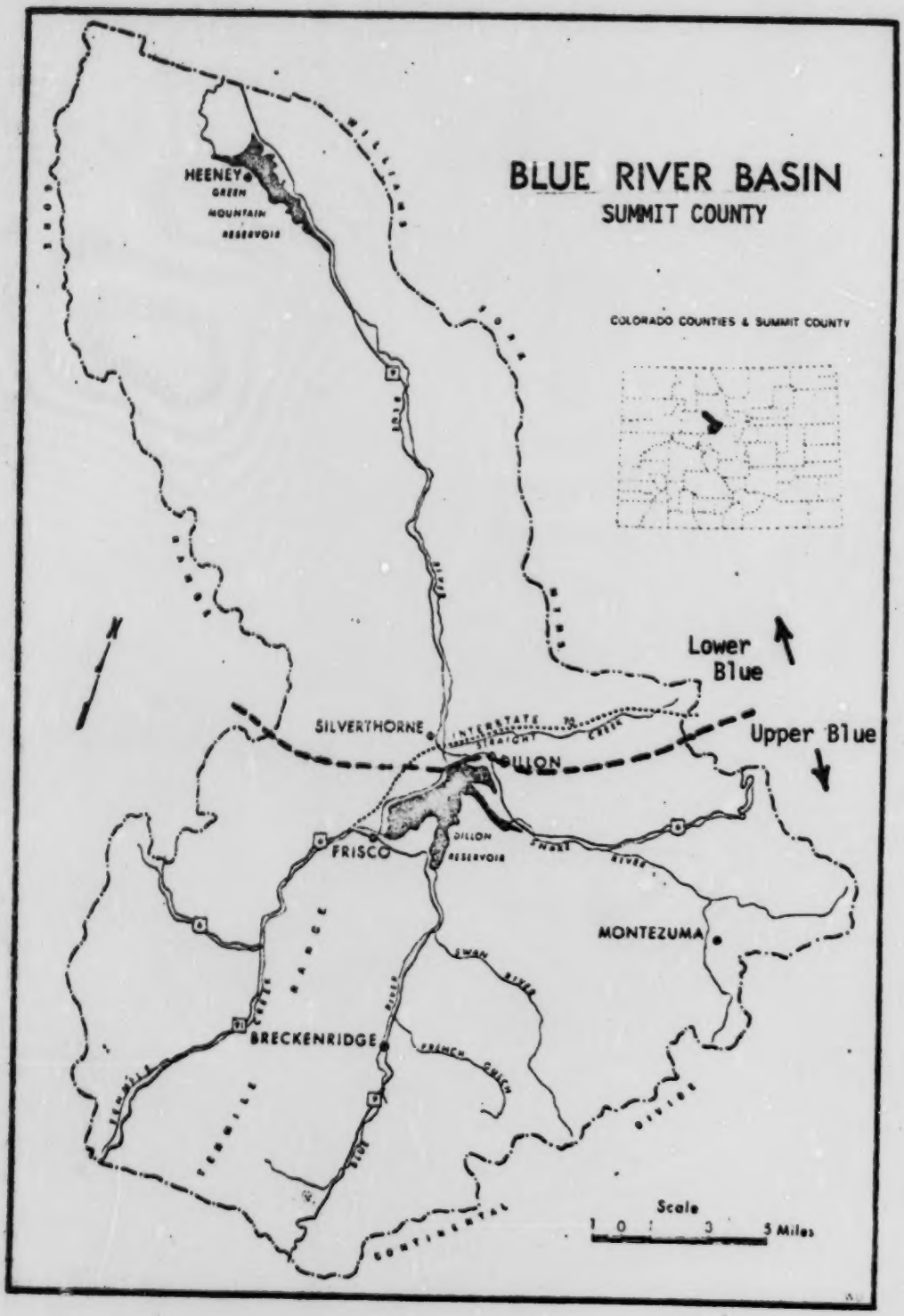
Summit County entirely encompasses the Blue River hydrologic basin to a point approximately three miles downstream of the outlet of Green Mountain Reservoir. For this reason it is a nearly ideal water quality management planning unit. Only approximately 10 stream miles of the Blue River lie outside of the county line before its confluence with the Colorado River near Kremmling. The Colorado Department of Health, Water Pollution Control Division, is the agency responsible for preparation of the basin plan for water quality management in cooperation with city and local governments.

For planning purposes, the Blue River Basin could be divided into andupper basin and lower basin, as denoted in Figures 2 and 3. The upper basin would encompass the Ten-Mile Creek, Snake River and Blue River drainages to the outlet of Dillon Reservoir. The lower basin would encompass all of the Blue River hydrologic basin below this point.

A. Basin Hydrology and Water Uses

The upper Blue River Basin is rimmed by high mountain watersheds on three sides, the majority of which lies within Arapahoe National Forest. Elevations in the upper basin range from over 14,000 feet to approximately 9017 at Dillon Reservoir. The lower Blue River Basiniis bordered by the Gore Range to the west and the Williams Fork Mountains to the east. No major tributaries enter the Blue River in this stretch, but numerous mountain streams feed laterally from the Gore Range.

FIGURE 2



by Will Ulman, University of Colorado

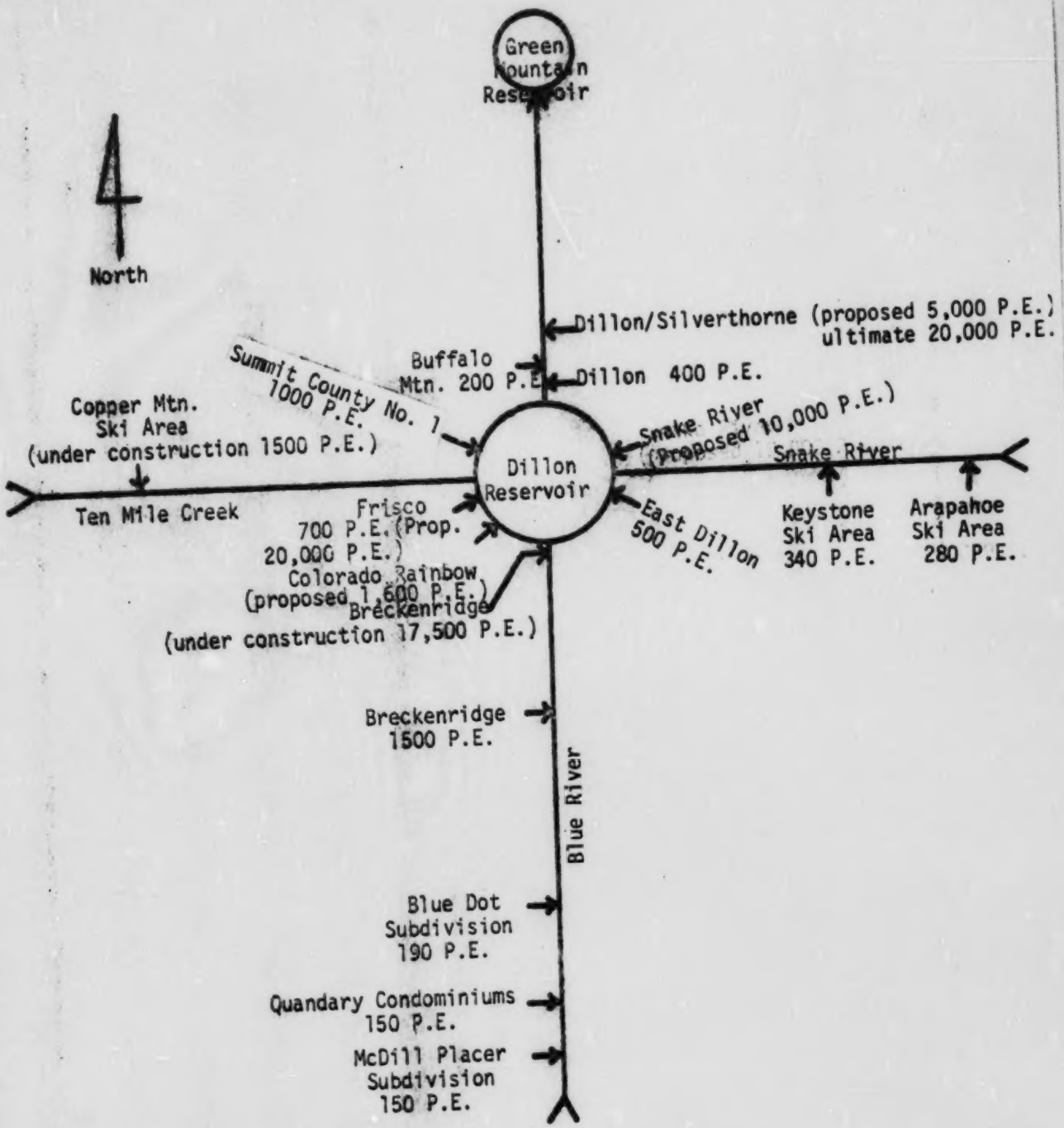

Green Mountain Reservoir
North
Dillon/Silverthorne (proposed 5,000 P.E.) ultimate 20,000 P.E.
Buffalo Mtn. 200 P.E.
Dillon 400 P.E.
Summit County No. 1 1000 P.E.
Copper Mtn. Ski Area (under construction 1500 P.E.)
Snake River (proposed 10,000 P.E.)
Snake River
Dillon Reservoir
Ten Mile Creek
Frisco 700 P.E. (Prop. 20,000 P.E.)
East Dillon 500 P.E.
Keystone Ski Area 340 P.E.
Arapahoe Ski Area 280 P.E.
Colorado Rainbow (proposed 1,600 P.E.)
Breckenridge (under construction 17,500 P.E.)
Breckenridge 1500 P.E.
Blue River
Blue Dot Subdivision 190 P.E.
Quandary Condominiums 150 P.E.
McDill Placer Subdivision 150 P.E.

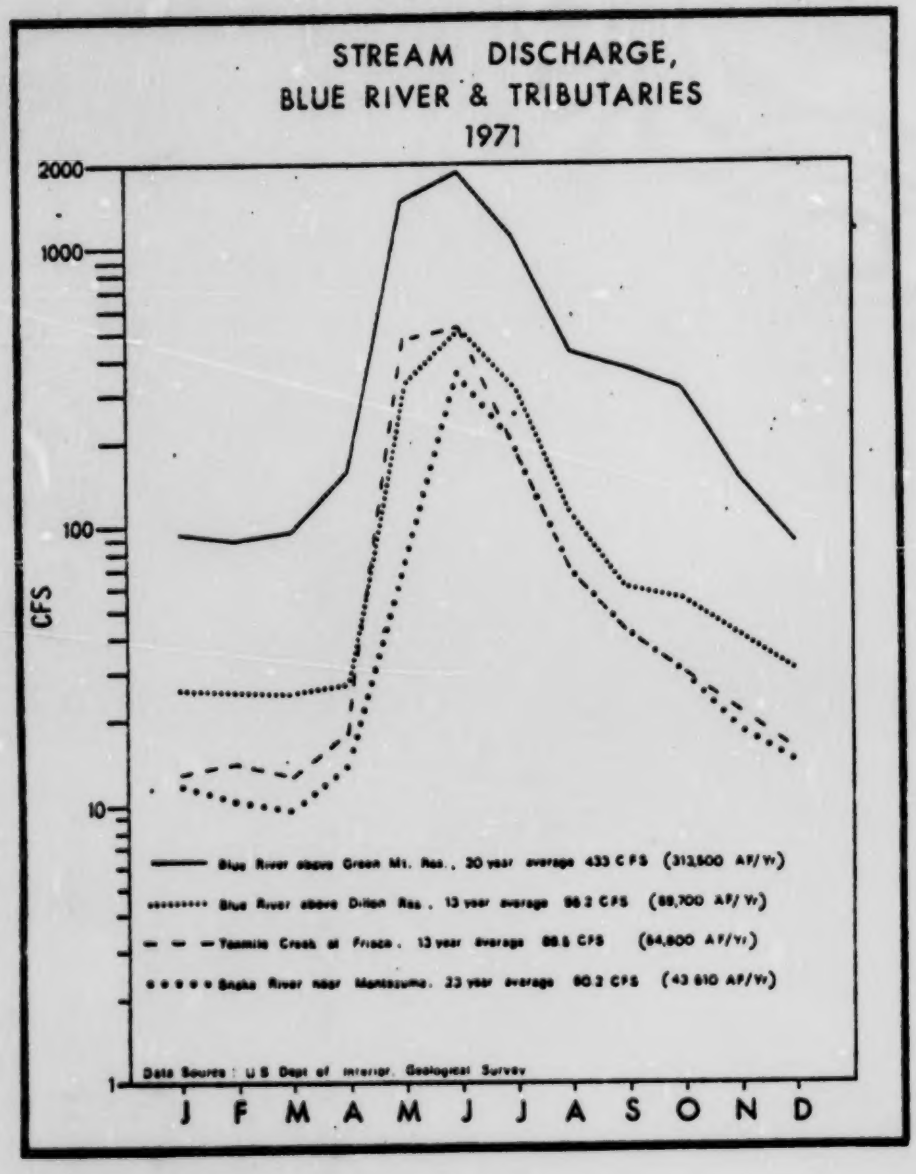
FIGURE 3

Major Domestic Dischargers

Streamflow is largely influenced by the snowfall accumulation and melting pattern in the high mountain watersheds. Nearly 70% of the average annual runoff occurs during the months of May, June and July. Runoff gradually recedes during the later summer, and minimum flows are normally recorded during the winter months. The standard deviation in the high runoff months is several orders of magnitude greater than in the low runoff months. This indicates that a wet or dry year is primarily determined by the amount of snowmelt occurring during the months of May, June and July. Figure 4 represents the relative contributions of tributaries to total streamflow in water year 1971.

Two major reservoirs are located in the Blue River Basin. Dillon Reservoir covers 2970 surface acres and has a storage capacity of 254,000 acre-feet. Green Mountain Reservoir is located 18 miles downstream of Dillon as indicated in Figure 2. Green Mountain Reservoir has a surface area of 2130 acres and a storage capacity of 154,600 acre-feet. Dillon Reservoir was constructed in 1964 and serves as part of the water supply network for the Denver Water Board. The Denver Water Board currently serves a population of 811,000 people in the Denver Metropolitan area with projection of a service population of 1,100,000 by 1985. The Denver Water Board has an allocation of 179,000 acre-feet of water per year from the Upper Blue River Basin. This appropriated water is diverted from Dillon Reservoir through the Roberts Tunnel and enters the North Fork of the South Platte River near Grant. Dillon water has not been used extensively by the Water Board to this date, but is planned to

FIGURE 4


STREAM DISCHARGE,
BLUE RIVER & TRIBUTARIES
1971
2000
1000
100
10
1
CFS
J F M A M J J A S O N D
Blue River above Green Mt. Res., 30 year average 433 CFS (313,500 AF/Yr)
Blue River above Dillon Res., 13 year average 98.2 CFS (69,700 AF/Yr)
Tenmile Creek at Frisco, 13 year average 88.6 CFS (64,800 AF/Yr)
Snake River near Montezuma, 23 year average 60.2 CFS (43,610 AF/Yr)
Data Source: U.S. Dept of Interior, Geological Survey

by Wil Ulman, University of Colorado

supply an increasing amount of the demand for water in the future. Plans for increased capacity in the Water Board's system call for diverting water from the Eagle-Piney Basins to Dillon Reservoir for a further increase in the amount of water which is stored in Dillon for later use.

Another possibility for increasing the amount of water inflowing to Dillon Reservoir is to intercept several of the small streams flowing from the Gore Range, such as Owl Creek, Cataract Creek, Black Creek, Rock Creek, Slate Creek, Boulder Creek, with the proposed Gore Range Aquaduct which would discharge to Dillon Reservoir. This would obviously effect the amount and time distribution of water reaching Green Mountain Reservoir.

The Blue River below Dillon Reservoir is regulated by releases from the reservoir. The minimum discharge (by agreements with the Denver Water Board) from Dillon Reservoir is 50 cfs or the total inflow amount if it is less than 50 cfs. The Denver Water Board also has an agreement to allow enough water to fill Green Mountain Reservoir in a water year to pass through the Blue River outlet of Dillon Reservoir.

Dillon Reservoir has become one of the largest water recreation areas in the State. Body contact recreation is prohibited, but existing uses include boating, sailing and fishing. Recreational use of the reservoir contributes substantially to the local economy.

B. Existing Land Uses and Developments

The recreation and second home development that is fast transforming vast areas of the Colorado Rockies into relatively dense urban landscapes is finding a focal point in Summit County, Colorado. In the true sense of the word, the county is witnessing a "boom" not surpassed even by the gold discovery days of the 1880's.

Although private deeded land holdings are limited in the county (90,775 acres out of 381,891, Figure 5), intensive development is occurring rapidly. Zoning densities in the R-25 to R-35 range are not uncommon.

Assuming that the prevailing growth trend will be continued in the future (an assumption followed by several consulting engineers in the county), the entire private portion of the developable land in the county will be developed for human occupance to some extent by the year 2000.

The overall factors of growth involved in the transformation of the county are not new to Colorado. "Skiburbs" resulting from the formation of winter sports sites and their resultant base area developments are quite common to the Colorado Rockies. However, Summit County is unique for the reason that it has been endowed with a profusion of existing and potential winter sports sites. At present, there are four sites with the potential existing for ten more (see Figure 6). Contingent upon the rejuvenation of study permits, it is estimated that only two additional sites may be developed in the near future (Ptarmigan and Brewery Hill). It is

FIGURE 5

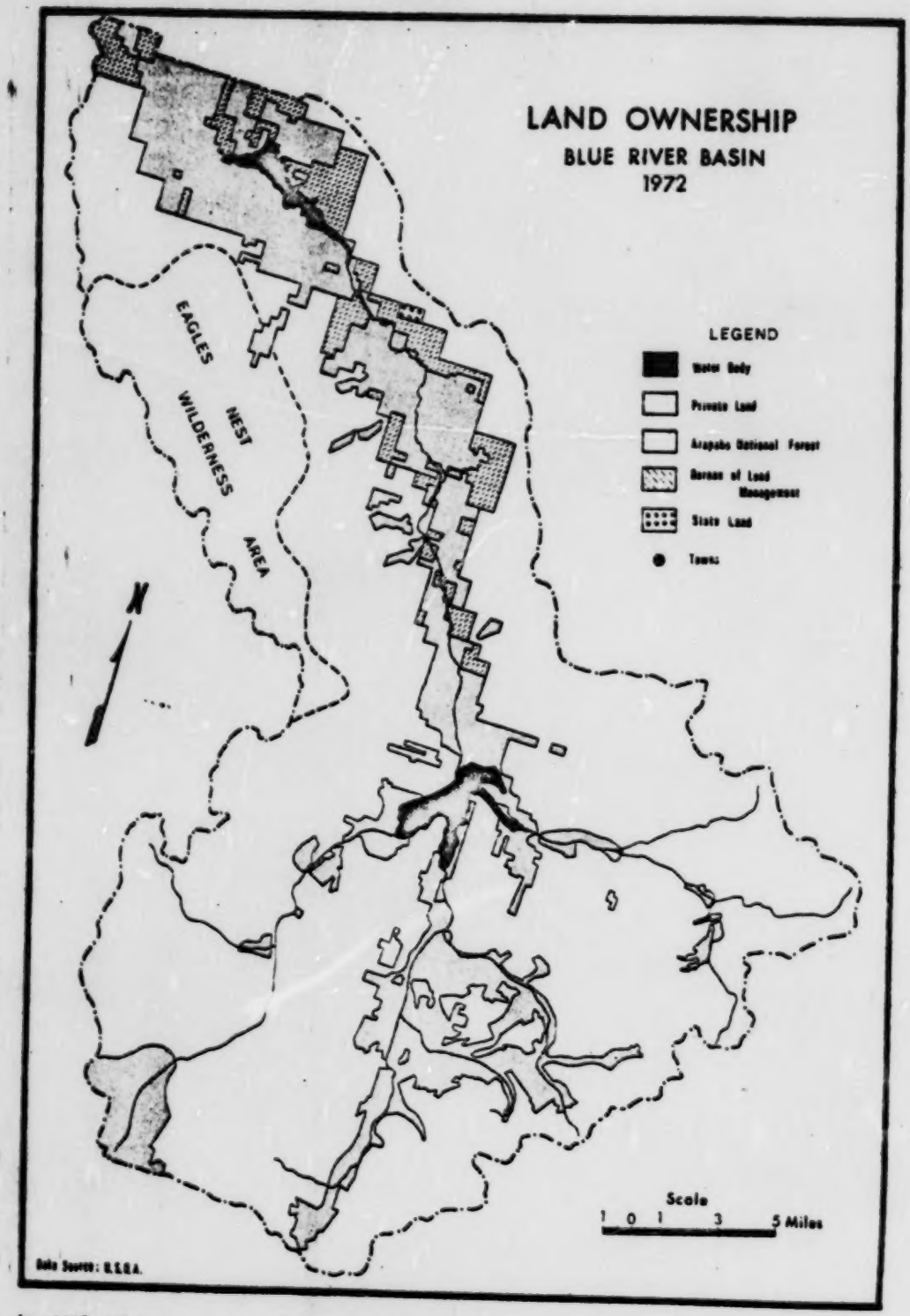


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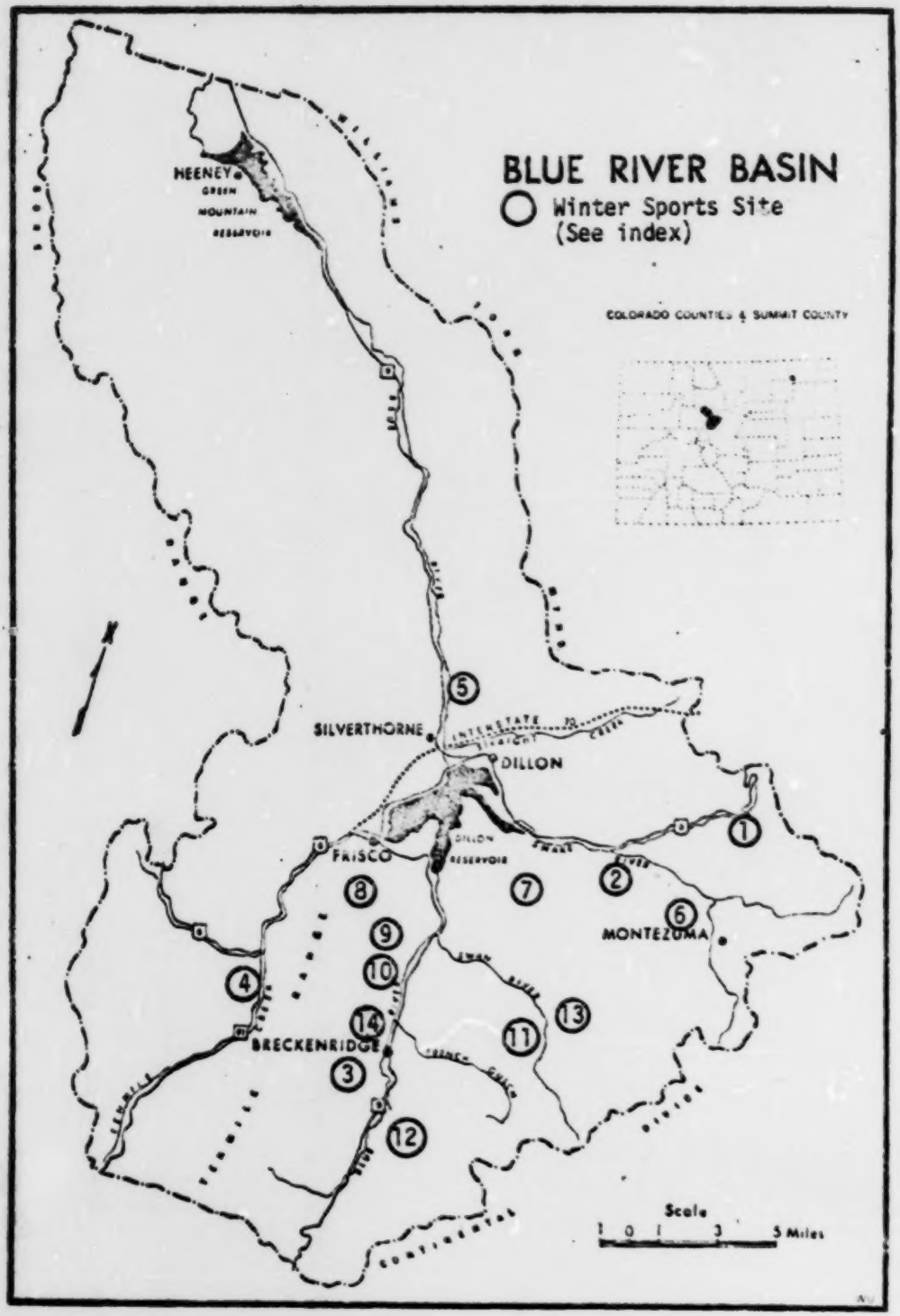
FIGURE 6


BLUE RIVER BASIN
Winter Sports Site
(See index)
COLORADO COUNTIES & SUMMIT COUNTY
HEENEY
GREEN MOUNTAIN RESERVOIR
SILVERTHORNE
DILLON
DILLON RESERVOIR
FRISCO
MONTEZUMA
BRECKENRIDGE
Scale
1 0 1 3 5 Miles

MAP INDEX TO WINTER SPORTS SITES

Existing or under development:

① Arapahoe Basin

② Keystone

③ Breckenridge (Peaks 8 and 9)

④ Copper Mountain

Potential:

⑤ Ptarmigan Peak

⑥ Independence Mountain

⑦ Swan Mountain

⑧ Peak One

⑨ North Barton

⑩ South Barton

⑪ Brewery Hill-Swan Valley

⑫ Mt. Argentine

⑬ Wise Mountain

⑭ Peaks 2-7

assumed that either existing areas will be further developed or additional sites will be developed if and when recreation demands warrant it. The established growth trend (1969-1972) in the use of Summit County's ski areas is 24% per year (Table 2).

The availability of recreation opportunity at a winter sports site is not the sole factor behind the continued growth in the county. The recreation/aesthetic attraction of Dillon Reservoir is a frequently neglected aspect of growth in the county.but Figure 7 and Table 3 graphically illustrate its significance. In 1970, there were 279,500 visitor days and the established growth trend (1965-1970) is 41.6%.

An additional factor to consider in the development of the county is the construction of Interstate 70. The land use impact of this major coast-to-coast transportation route will be significant. Projected traffic growth for the county is more than twice the state average (see Figure 8).

Traditionally, west or east bound travellers have bypassed Colorado by travelling I-80, I-90 or I-40 to avoid the inconvenience of Colorado's high mountain passes. I-70 will in effect make travelling through Colorado more appealing to out-of-state travellers as well as make Summit County more accessible to Front Range residents and possible home to work commuters.

In summation, the impact of the ski industry, Dillon Reservoir, and I-70 lends credence to the county's high projected ultimate populations.

TABLE 2

USE OF SUMMIT COUNTY SKI AREAS
(in thousands)

	Visits 69-70 Season		Visits 70-71 Season		Visits 71-72 Season	
	Skiers[1]	All Users	Skiers	All Users	Skiers	All Users
Arapahoe Basin	144.8	149.8	107.2	112.5	94.7	184.6
Breckenridge	168.8	175.5	200.6	209.3	221.5	388.7
Copper Mountain					0.7	0.7
Keystone			73.6	76.7	148.6	151.7
TOTAL	313.6	325.3	381.4	398.5	465.5	725.7

Legend:

1. A skier visit is a visit of any duration to an area for a single day, generally by an individual who bought a tow ticket or had a season pass and used it for a single day.

Data Source: U.S. Forest Service, Denver, Colorado

TABLE 2A. List of Inventoried Winter Sports Sites
Summit County, Colorado

Appraiser Rating[1]	Winter Sports Site	Skier Capacity[2]
G	Brewery Hill & Swan Valley	3-5,000 +
1-0	Copper Mountain	5,000
G	Independence Mountain	3,500
2-0	Keystone	5,000
M	Mt. Argentine	Less than 1,000
G	North Barton	2,000 +
1-3-G	Peak Nine	2,000 +
U	Peak One	2,000 +
U	Peaks Two-Seven	---
G	Ptarmigan Peak	2-3,000
M	South Barton	2,000 +
U	Swan Mountain	1-2,000
M	Wise Mountain	1-2,000
4-0	Arapahoe Basin	3,000
4-0	Breckenridge	4,300

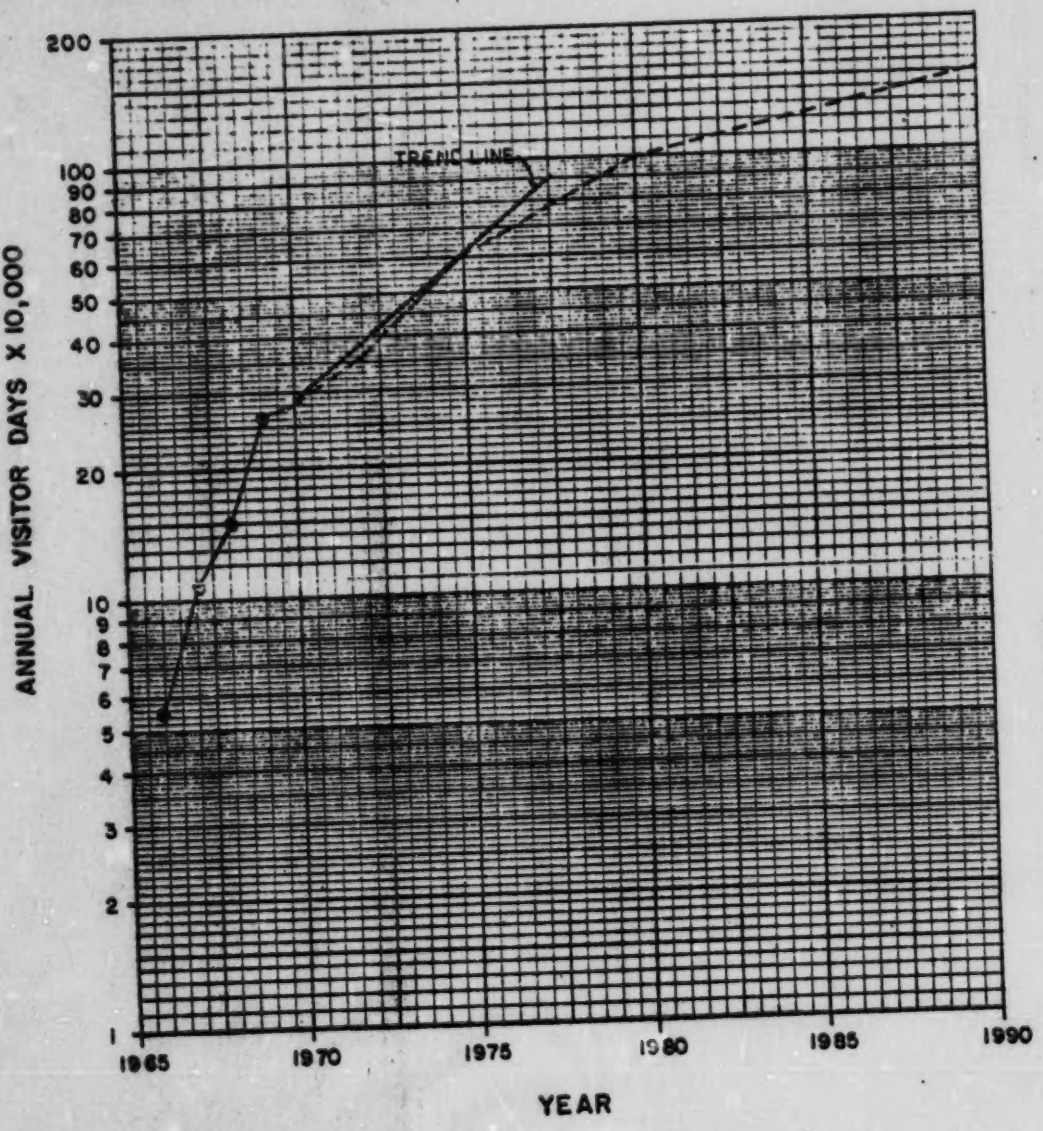
Legend:

1. (1) Under Development
   (2) Expansion of Existing Area
   (3) Study Permit
   (4) Existing
   (0) Outstanding
   (G) Good
   (M) Marginal
   (U) Unacceptable
2. Skier capacity is defined as capability of each skier making at least two runs per hour.

Data Source: U.S. Forest Service, Denver, Colorado

FIGURE 7

DILLON RESERVOIR
PROJECTED FUTURE RECREATIONAL USE (1)



(1) Assumes unlimited facilities available for recreational use around the Reservoir.

Data Source: U.S. Forest Service

Table 3

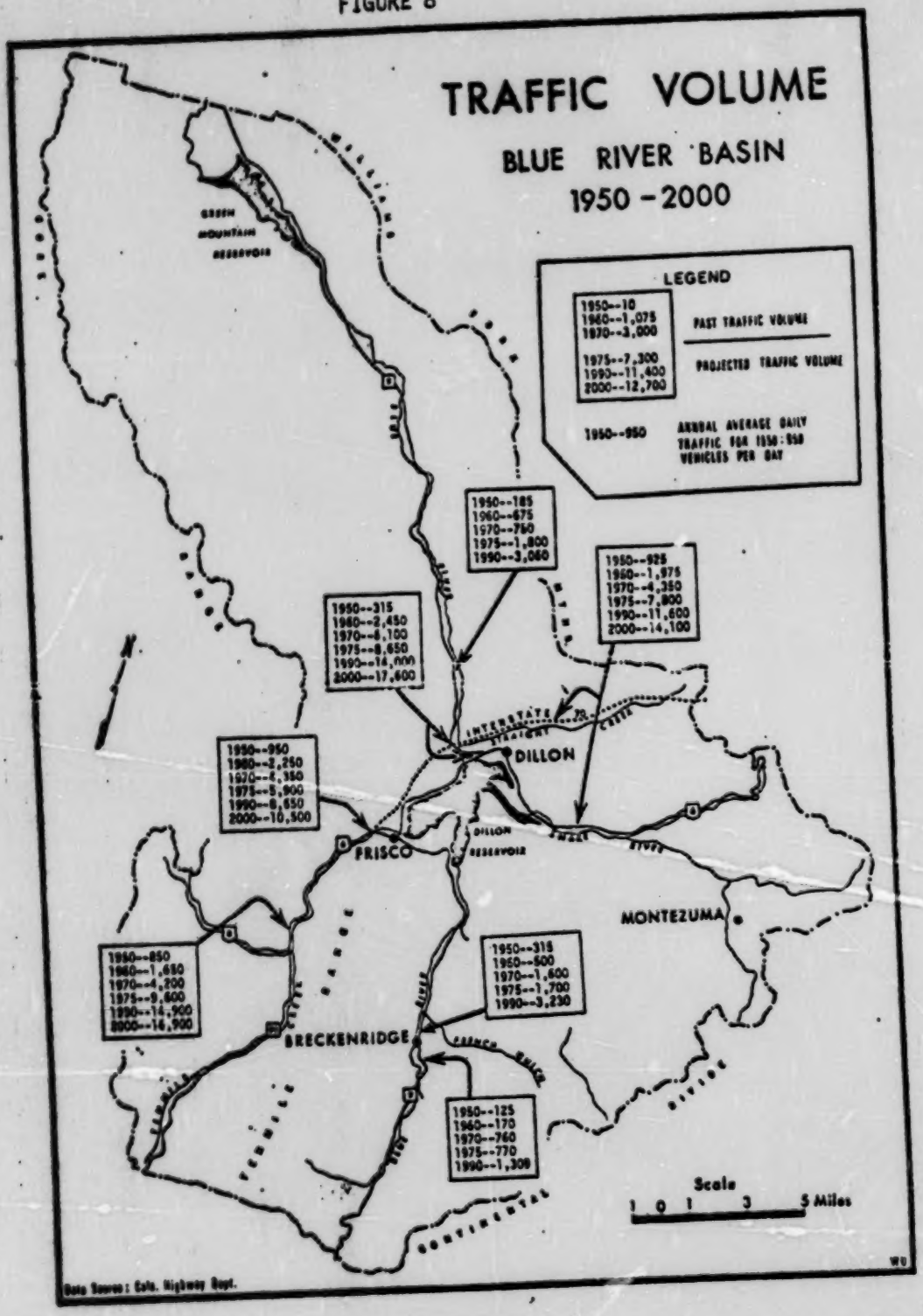
DILLON RESERVOIR
HISTORICAL VISITOR USE DATA (1)

		1965		1966		1967		1968		1969		1970
	PAOT	Visitor Days	Visits	Visitor Days	Visits	Visitor Days	Visits	Visitor Days	Visits	Visitor Days	Visits	Visitor Days
Frisco Boat Launch	350					2,100	5.2	5,500	10.1	9,800	19.6	10,800
Snake River	100		4.8	400	4.8	1,600	3.8	3,300	6.4	5,800	11.6	6,400
Dillon	100		7.2	600	7.2	4,800	12.6	5,100	10.2	9,000	18.0	9,900
Frisco Bay	200		5.0	500	5.0	2,100	4.5	3,000	6.0	5,300	10.6	6,500
Blue River	100		3.4	300	3.4	2,400	5.4	3,100	6.2	5,400	10.8	6,000
Giberson Bay	100					2,100	5.4	2,800	5.4	5,000	10.0	5,500
Windy Point	200							2,700	5.4	4,800	9.6	5,300
Snake River	60		.3	600	1.4	600	1.7	1,300	1.9	2,300	4.6	
Peak One	380			8,100	12.3	21,200	21.2	39,700	39.7	57,500	57.5	63,300
Prospector	535			16,600	24.9	14,800	14.8	23,300	23.3	49,600	49.6	54,600
Heaton Bay	430		20.4	16,700	40.0	44,900	47.5	54,000	54.0	77,100	77.1	84,800
	2,555		41.1	43,800	99.0	96,600	122.1	143,800	168.0	231,600	279.0	253,100
Rainbow Lake	50									900	1.8	1,000
Officers Gulch	95			11,200	26.9	10,300	10.3	6,800	6.8	23,000	23.0	25,400
Total				55,000	125.9	106,900	132.4	150,600	174.8	265,500	303.8	279,500
Annual Growth Rate												41.6%

(1) Data supplied by Forest Service. Visits should be multiplied by 1000.

E-4
A

FIGURE 8



by Wil Ulman, University of Colorado

C. Projected Land Uses

According to the Summit County Planner, there are currently 90 active subdivisions in Summit County representing 4,892 lots on 4,920 acres. In these lots are planned 12,962 individual living units, all of which are in some phase of construction. In addition, there are 1,790 acres averaging R-6 zoning which has been approved for development. This would permit an additional 8,892 living units. There are 3,600 acres that have plans for development which would represent 12,000 units. In the five incorporated towns, there are 21,000 units. In total, there are existing, under construction or planned, 54,854 living units in Summit County.

The total acreage that is developed or planned to be developed is 11,618 acres. This represents 12.8 percent of the total deeded land in the county. Even considering that all deeded lands are not suitable to development, the current land use trend is the replacement of the remaining agricultural and mining uses with residential and recreational uses. This trend should continue to some extent until political, environmental or social pressures dictate differently.

III. POPULATION TRENDS AND FORECASTS

At the present time there are several estimates of present and future populations in the county (Figure 9). Some degree of ambiquity exists for these projections in that population is not fully defined in terms of contributory (visitor days or recreation visits) or resident.

A. Based on a comprehensive plan completed by Ray and Associates, a 1992 population of 64,831 is forecast and an ultimate population of 121,183 for just the Upper Blue River Basin from the mouth of the Blue River on Dillon Reservoir to Hoosier Pass. These estimates were based on available developable land and established growth trends.

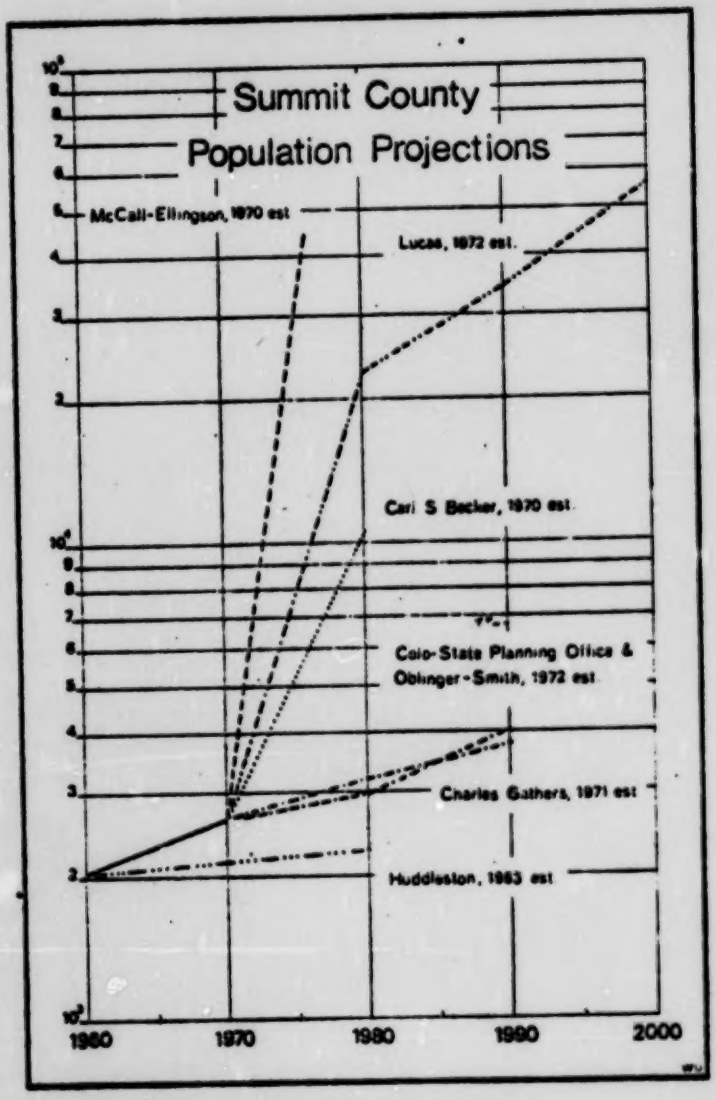
B. In a 1970 county sanitary sewer system report by T. V. Garel (McCall-Ellingson), an ultimate contributing population for the county of 178,800 is projected. A population of 44,000 for the 1976-77 season is also projected. These populations are based on available developable land and projected contributing population of winter sports sites.

C. By considering the amount of existing approved subdivisions, the county has estimated that 150,000 people could be accommodated in the Upper Blue River Basin (including Ten Mile and Snake River) and 180,000 + for the entire county. This estimate is based on a factor of 3.5 individuals per approved living unit.

D. A 1970 planning report by Carl S. Becker Company, Denver, Colorado, estimated the 1980 population for Summit County, Colorado to be 11,711.

E. Charles Gathers and Associates, Inc., Denver Consultants, in a 1970 comprehensive plan for Summit County, estimated that by 1990 Summit County would contain a 3,800 permanent year-around population and a seasonal peak population of 30,000.

FIGURE 9



by Wil Ulman, University of Colorado

F. Oblinger-Smith Corporation, Denver, Colorado, using data supplied by the Colorado State Planning office, completed an FHA Water and Sewer Facility Plan for Summit County, Colorado in 1972 that estimated the 1990 population to be 4,000.

G. Sam L. Huddleston, Denver Planner, in 1963, completed a report "Summit County, Colorado: The Master Plan" which estimated the 1980 population to be 2,300.

H. Possibly the most sophisticated approach to population projections has been completed by Therese Lucas for the Colorado Land Use Commission (Table 4). The methodology utilized is based not only on established growth trends but on the ski industry's impact and the holding capacity of the developable land. Lucas' estimate of 55,800 by year 2000 is permanent residents. Considering that other estimates in the county are based on both contributing and permanent residents, this figure is likely to be conservative as it applies to the generation of domestic wastes, both solid and liquid, and service and resource demands and requirements. This would be especially applicable if permanent residences were fully occupied during a peak ski visitor weekend. Another factor that was not involved in the population projection was the impact of I-70. With a commuting time of one hour to Western Denver, commuter population is certain to increase as well as a significant day user recreation population.

Whatever is conceived as being the most accurate population projection is, at this time, not an issue. What is significant is that few constraints exist for limiting or controlling the urbanization of the county and from all indications this will not change. Existing

comprehensive land use plans, engineering studies, population projections and zoning, all point to a recreationally oriented mountain conurbation with a day population from 150-200,000 people.

TABLE 4

GROWTH PROJECTIONS FOR SUMMIT COUNTY, COLORADO

	1980	1990	2000
Population	22,500	34,240	55,800
Employment	8,560	13,000	21,200
Dwelling Units	14,300	22,220	29,190
Water Demand (acre feet)	17,538	13,014	16,847
Sewage Demand (mgd)	2.6	3.63	5.79
Acreage in Residential Development	4,767	7,407	9,720
School Enrollment	14,300	22,220	29,170

BY: Therese C. Lucas
Draft Technical Paper No. 2
Colorado Projections: 1980, 1990, 2000 and Methodology
November 16, 1972.
Prepared for the Colorado Land Use Commission.

IV. WASTE LOADINGS

As previously defined, the Blue River hydrologic basin has been separated into an upper basin and a lower basin, for purposes of evaluating the water quality impact of existing and proposed waste loadings on both Dillon and Green Mountain Reservoir. The upper Blue River Basin is defined as the Blue River, Snake River and Ten Mile Creek Basins and all other tributaries to Dillon Reservoir. The lower basin is defined as the Blue River below Dillon Reservoir and all of its tributaries.

Because of the concern for avoiding a possible eutrophic condition in either Dillon or Green Mountain Reservoir, nutrient sources to these reservoirs will be of particular concern. The sources of waste entering the system which will be evaluated include both point and non-point sources. Point sources include municipal and industrial waste discharges as well as urban storm drainage. Non-point sources include the natural background loadings from leaching of soils, agricultural runoff and return flows, and wastes produced by the actions of man disturbing the natural cover and inducing erosion.

A. Present Waste Loadings

1. Upper Blue River Basin

The upper Blue River Basin presently has 10 domestic waste treatment plants which discharge their wastes to streams eventually reaching Dillon Reservoir. The total treatment capacity of these plants is approximately .5 MGD. The majority of these plants were built before the Summit County Standards for wastewater treatment were adopted, and hence do not provide for phosphorous removal. Also, a majority of the plants are

designed for less than 0.1 MGD and are of the type commonly referred to as "package plants."

Waste loadings are highly variable due to the seasonal and weekend peak characteristics exhibited by the recreational use of facilities in the area. Such areas typically exhibit peak loadings during the winter ski season and summer water recreation season with weekend peaks superimposed on the annual pattern. The annual waste loading of recreational areas approximates a sinusoidal shape as represented in Figure 10. Peak loadings occur in early January and again in July. Minimum waste loadings occur in April and again in October[1]. Several of the existing plants are grossly overloaded at peak flows. Existing waste loads, however, are predicated on design capacity only.

Based on data collected by the Denver Water Board, the average influent quality of sewage to the major treatment facilities is: 250 mg/l BOD_5, 7.5 mg/l PO_4 as P, and 30 mg/l TKN. The data from the Denver Water Board was also analyzed in order to develop the current waste loadings from actual plant treatment efficiencies as shown in Table 5. The present waste loadings probably underestimate the current waste loadings at peak flows since several of the major treatment plants are overloaded under these conditions. However, there is no available data on the actual amount of flow

1. From Aspen Metropolitan District records.

FIGURE 10. Total Waste Loads for Constituents as a Function of Time

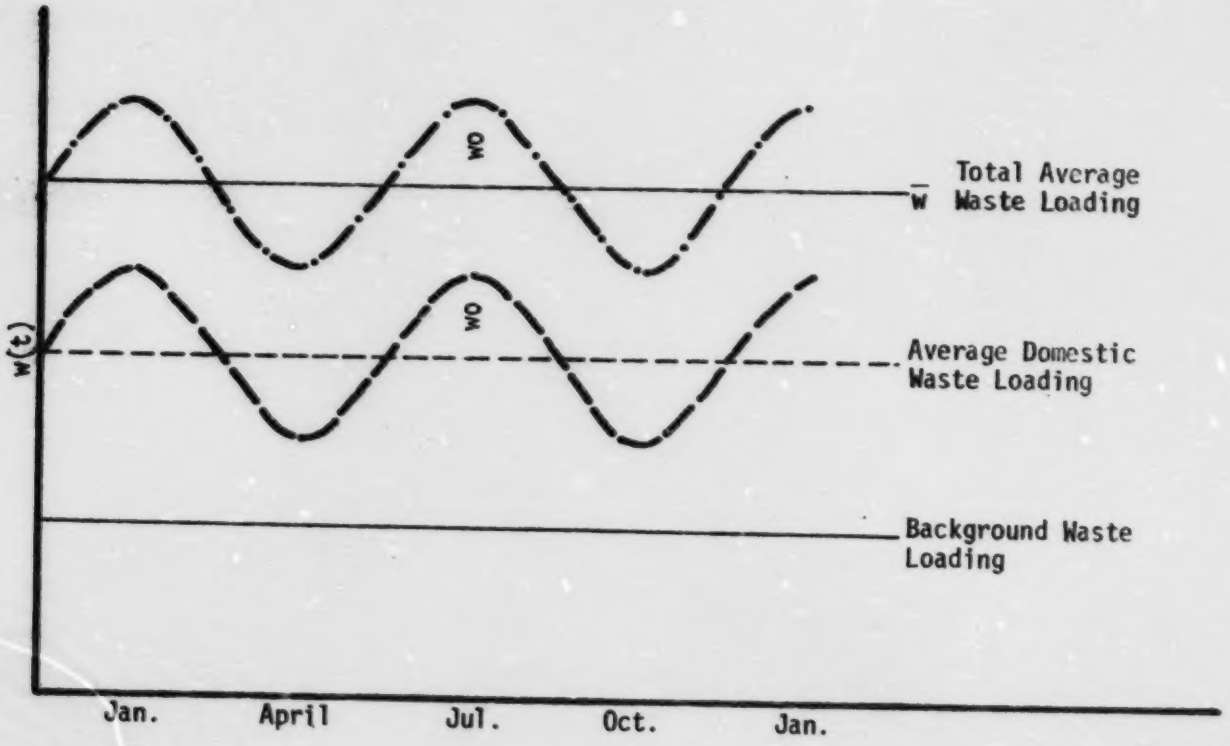


TABLE 5. Present Domestic Waste Loadings

	Average Effluent Quality for Major Treatment plants in Upper Blue Basin			
Constituent	BOD_5	TKN	$NO_2 + NO_3$	PO_4 as P
Concentration	15 mg/l	15 mg/l[1]	15 mg/l[1]	7.5 mg/l
Total Load (0.5 MGD Assumed)	63 lb/d.	63 lb/day	63 lb/day	31 lb/day

leaving each of the treatment plants. The above figures represent the waste loadings at plant design capacity only.

The background waste loading from natural and man induced sources was also obtained from data taken by the Denver Water Board. This data was supplemented with data taken from watersheds under intense development similar to that of the Upper Blue Basin at Lake Tahoe, California. The background data available on the Upper Blue corresponds well with values taken for watersheds under intensive development at Lake Tahoe. At Lake Tahoe, the values for nutrients entering a disturbed watershed were nearly twice that which entered an undisturbed or nearly virgin watershed. Another background source of nutrients which is not included in the loadings because of lack of data is nutrients entering the system adhered to soil particles which are eroded and are carried in the bed load of the stream. This material will normally settle to the

1. This is based on the assumption that 50% of the TKN is nitrified during treatment and only minimal removal of total nitrogen is achieved.

bottom upon entering a relatively quiescent body such as a lake. However, this material may be solubilized by anaerobic bacteria under certain conditions.

The nutrient and BOD loadings from background sources are summarized in Table 6.

TABLE 6. Background Waste Loadings

Constituent	BOD_5	TKN	$NO_2 + NO_3$	PO_4 as P
Concentration	1.25	0.25 mg/l	0.05 mg/l	0.1 mg/l
Total Load (At 280 cfs avg. discharge)	1725 lb/day	345 lb/day	69 lb/day	138 lb/day

2. Lower Blue River Basin

The lower Blue River Basin currently has 4 domestic waste discharges, with a total population equivalent of 5600 persons (0.56 MGD) at capacity. This includes the Silverthorne plant which is currently under construction and has a capacity of 0.5 MGD. In addition, a portion of the non-degraded wastes which are discharged to Dillon Reservoir eventually reach the lower Blue River. The other portion would presumably be discharged to the North Fork of the South Platte River through the Roberts Tunnel. The reservoir acts as a dampening and detention device and therefore peak loads would be dampened out.

The direct waste loadings to the Lower Blue River are summarized in Table 7. The Silverthorne plant is assumed

to provide treatment equivalent to the requirements of the Summit County Standards.

TABLE 7. Direct Domestic Waste Discharges to Lower Blue River Basin

Constituent	BOD_5	TKN	$NO_2 + NO_3$	PO_4 as P	Total Design Capacity
Concentration	5.0 mg/l	15 mg/l	15 mg/l	.38 mg/l	0.56 MGD
Total Load (At Design Capacity)	21 lb/day	62.5 lb/day	62.5 lb/day	1.6 lb/day	

B. Proposed Waste Loadings

1. Upper Blue River Basin

Current proposals for domestic waste treatment plants in the Upper Blue River Basin would bring the total plant capacity discharging to Dillon Reservoir to 52,370 population equivalent (5.2 MGD). This is an increase of ten-fold in treatment plant capacity, representing the dramatic growth taking place in the upper basin. From population projections it is anticipated that the proposed expansions will be sufficient to serve the upper basin until 1975.

The following tables are a summary of existing and proposed capacities and discharges for waste water treatment plants in the upper basin.

Existing Plants (Rec. Waters)	Design Population Equiv.	Plants Under Construction or Approved (Rec. Waters)	Design P.E.	Plants Proposed for Construction or Expansion (Rec. Waters)	Design P.E.
Summit County #1 (Dillon Reser.)	1000	Breckenridge (Dillon Reser.)	17,500	Frisco (Dillon Res.)	20,000
Frisco (Dillon Reser.)	700	Copper Mtn. (Ten Mile Creek)	1,500	Colo. Rainbow Enterprises (Dillon Res.)	1,600
Breckenridge (Blue River)	1500			Snake River (Dillon Res.)	10,000
Arapahoe Ski Basin (Snake River)	280				
East Dillon Summit Co. Dillon Res.	500				
Keystone Ski Area (Snake River)	340				
Blue Dot Subdivision (Blue River)	190				
Quandary Condominiums (Blue River)	150				
McDill Subdivision (Blue River)	150				
TOTAL	4810		19,000		31,600

Total Existing, Approved, and Proposed = 52,370 P.E. (Includes the phasing out of existing Frisco, Breckenridge, Keystone and East Dillon Plants.)

TABLE 9. Domestic Waste Loadings in Upper Basin Under Proposed Levels of Development

Constituent	BOD_5	TKN	$NO_2 + NO_3$	PO_4 as P	Total Design Capacity
Concentration	5.0 mg/l	15 mg/l	15 mg/l	.38 mg/l	
Total Load	218 lb/day	650 lb/day	650 lb/day	16.3 lb/day	5.2 MGD

Background waste loadings are assumed to remain constant for the proposed level of development, although the surge of development which would follow the construction of the proposed plants might result in even heavier background loadings occurring. Also, sludge handling practices, if not adequately planned, could produce additional nutrient loadings from leachate.

2. Lower Blue River Basin

The lower basin has only a proposal for an additional wastewater treatment plant at the Rock Creek site. This would service the area below the Silverthorne Plant and above the confluence with Rock Creek and would have a design population equivalent of 10,000. Table 10 represents the expected total effluent loading to the Lower Blue River after expansion.

TABLE 10. Direct Domestic Waste Loadings in Lower Basin Under Proposed Levels of Development

Constituent	BOD_5	TKN	$NO_2 + NO_3$	PO_4 as P	Total Design Capacity
Concentration	5.0 mg/l	15 mg/l	15 mg/l	.38 mg/l	
Total Load	65 lb/day	195 lb/day	195 lb/day	5.0 lb/day	1.56 MGD

C. Waste Loadings at Ultimate Development

1. Upper Blue River Basin

At ultimate, or saturated levels of development, the contributing population discharging to the upper Blue River Basin would be 105,000 population equivalent at peak seasons. It is difficult to estimate the time at which this saturation would occur with any degree of accuracy because long-range estimates for population are dependent upon many contributing factors. This projection is based upon the developing of existing subdivided land with densities continuing at present levels. This increase in population would require an additional expansion of wastewater treatment plants to a total capacity of 10.5 MGD. This would give a twenty-fold increase from present treatment capacities and a doubling of capacities from the current proposals. Table 11 represents the waste loadings to the Upper Blue River Basin at ultimate development levels.

TABLE 11. Domestic Waste Loadings in Upper Basin Under Ultimate Levels of Development

Constituent	BOD_5	TKN	$NO_2 + NO_3$	PO_4 as P	Total Design Capacity
Concentration	5.0 mg/l	15 mg/l	15 mg/l	.38 mg/l	
Total Load	435 lb/day	1310 lb/day	1310 lb/day	33.0 lb/day	10.5 MGD

2. Lower Blue River Basin

Population projections for the Lower Blue River Basin predict a total contributing population equivalent of 50,000 at

peak seasons. This would require expansion of the present domestic waste treatment facilities from 0.56 MGD to 5.0 MGD. The direct waste loadings from the Lower Blue River Basin are summarized in Table 12.

TABLE 12. Direct Domestic Waste Loadings in Lower Basin at Ultimate Levels of Development.

Constituent	BOD_5	TKN	$NO_2 + NO_3$	PO_4 as P	Total Design Capac.
Concentration	5.0 mg/l	15 mg/l	15 mg/l	.38 mg/l	
Total Load	210 lb/day	625 lb/day	625 lb/day	16 lb/day	5.0 MGD

V. WATER QUALITY IMPACT

The water quality impact of the proposed expansions on Dillon and Green Mountain Reservoir was analyzed by two different methods. First, both reservoirs were assumed to be completely mixed in the vertical dimension, with no significant variations in water quality parameters at various depths in the reservoirs. A second analysis was performed on Dillon Reservoir using available information on thermal stratification which will significantly effect water quality. The thermally stratified case requires a much more complex analysis taking into consideration variations in water quality, temperature, waste discharges, inflow rates and reservoir withdrawal rates and locations throughout the year. The physical configuration of the reservoir and location of withdrawals within the reservoir also become significant.

Dillon Reservoir has been shown to be a deep, well stratified reservoir as indicated in Figure 11, which shows the development of the thermocline at a depth of approximately 30 feet during the late summer. Dillon has a densimetric Froude Number, F_R = .0007, as compared to other highly stratified reservoirs which have been studied with F_R ranging from 0.003 to 0.0026, with lower Froude Numbers corresponding to higher levels of stratification.

Green Mountain Reservoir has a smaller storage capacity and a higher inflow rate than Dillon and therefore does not exhibit such strong effects from stratification. Green Mountain Reservoir was only analyzed in the completely mixed case assumption.

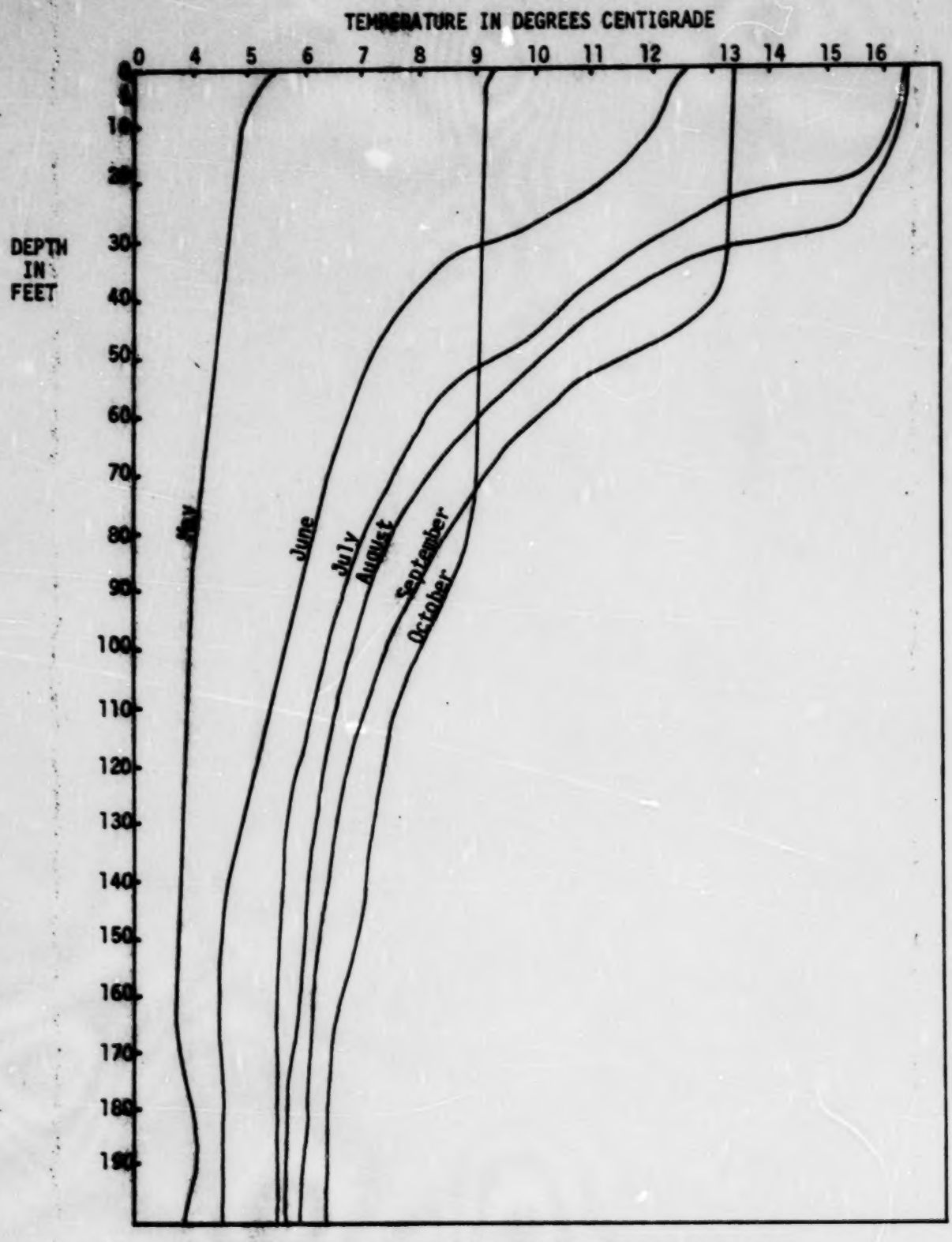


FIGURE 11. DILLON RESERVOIR TEMPERATURE STRATIFICATION

A. Completely Mixed Analysis

As a first approximation to resultant water quality from waste discharges to the reservoirs, the assumption of a completely mixed system with no concentration gradients in the vertical dimension is a useful tool in planning for water quality management. Basically, the reservoir will receive an input amount of a given constituent and simultaneously lose a given amount through outflows from the system and decay of the constituent where applicable. A simple materials balance for the system yields the differential equation:

(1) $V \frac{ds}{dt} = w(t) - Q(s) = KVs$

where: V = volume of the reservoir (completely mixed)

s = concentration of constituent

k = first order decay coefficient for constituent

q = flow through the reservoir. (Inflow assumed = outflow)

t = time

The equilibrium solution to the above equation for a constant waste loading is: (2) $\bar{s} = \frac{\bar{w}}{Q + KV}$

where: $\bar{w}$ = waste loading (lb/day)

For a variable waste input, w(t), approximating a sinusoidal function, the solution to the differential equation is:

(3) $Sp = W_o \, A_m(w) \sin[wt - \alpha - \phi(w)]$

where: w_o = amplitude of waste loading variation

$A_m(w) = [\frac{1/V}{(K/V)^2 + w^2}]$: amplitude characteristic

$\phi(w) = \arctan(\frac{w}{K/V})$: phase shift characteristic

w = frequency of waste loading cycle

k = Q + KV

α = phase shift

Combining these two equations, [(2) and (3)], the completely mixed system can be viewed as the result of a constant waste loading (background plus average domestic loads) and a variable waste loading (variation in domestic waste loading) as shown in Figure 10. In simple terms, the resultant concentration of any time will be the sum of $\bar{s}$ and Sp.

The analysis of the water quality impact by the completely mixed analysis has several disadvantages. First, it is not possible to include the effects of the random variations in the inflow and outflow to the reservoir and the changing volume of storage, which may either increase or decrease the resultant equilibrium concentrations. Second, it is not possible to include the effects of the diversion of water and nutrients from the Roberts Tunnel in Dillon Reservoir, which means that a large percentage of the nutrients may never reach Green Mountain Reservoir but instead be discharged to the S. Platte Basin and eventually deposited in the proposed Two Forks Reservoir. A third disadvantage is the problem of predicting the amount of phosphorus stored by resident algal populations. Because it is not possible to include the effects of time varying reaeration using the completely mixed analysis, it is not possible to predict the dissolved oxygen level in any part of the reservoir.

1. Solution for Present Loadings (Completely Mixed Analysis)
   a. Existing waste loadings are formulated on background loadings remaining constant throughout the year and domestic waste loadings following a sinusoidal pattern throughout the year with peaks occurring in January

and July and minimums occurring in April and October. Waste loadings from all domestic plants are predicated on minimum waste loads consisting of 55% of the peak waste load as shown in Figure 12. The use of this percentage of peak loadings seems to be verified by population projections for full time residents of Summit County prepared by the Colorado Land Use Commission.

b. Resultant Concentrations in Reservoirs

From the waste loads presented in Tables 13 and 14 for present domestic and background waste loadings, the equilibrium concentrations obtained using the completely mixed analysis are presented below.

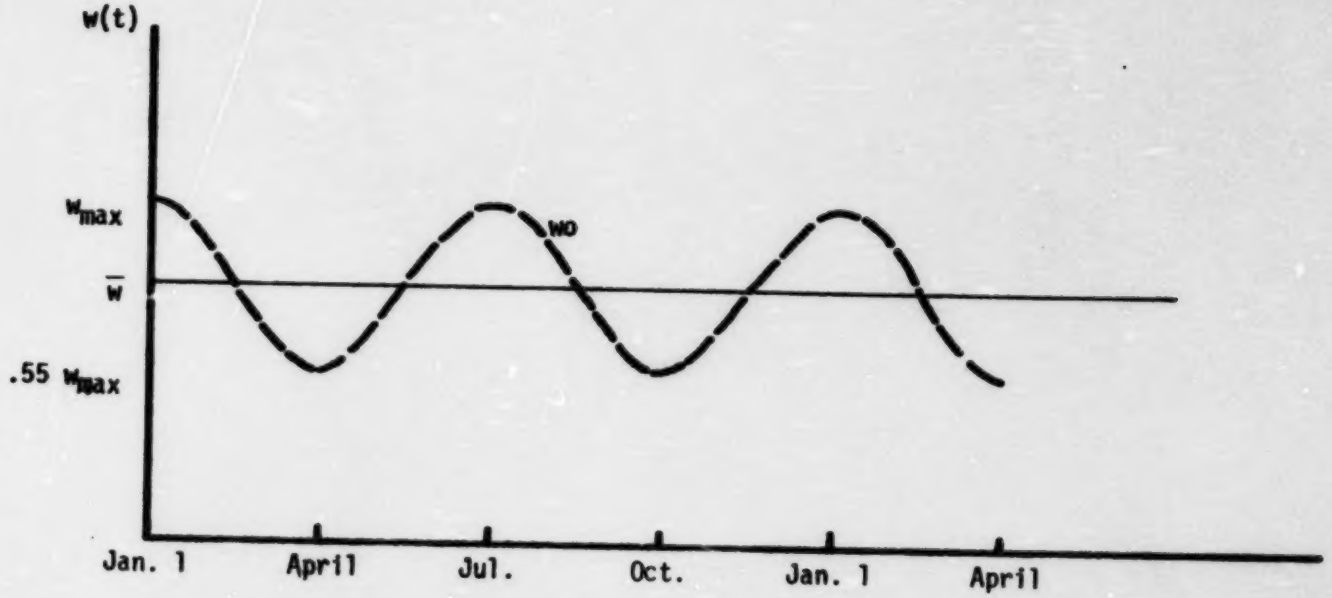
TABLE 13. Completely Mixed Concentrations in Dillon Reservoir Under Present Loadings

	TKN	NO_2 + NO_3	Total Nitrogen	PO_4 as P
Concentration	0.276 mg/l	0.094 mg/l	0.370 mg/l	0.115 mg/l

TABLE 14. Completely Mixed Concentrations in Green Mountain Reservoir Under Present Loadings

	TKN	NO_2 + NO_3	Total Nitrogen	PO_4 as P
Concentration	0.228 mg/l	0.066 mg/l	0.294	0.101

FIGURE 12. Domestic Waste Loads as a Function of Time



The time to reach equilibrium concentrations for each of the reservoirs is a function of reservoir storage, inflow, and waste loadings. For Dillon Reservoir, the time to reach 65% of the equilibrium concentrations is 1.26 years. To reach 95% of the equilibrium concentration would take 3.75 years.

The actual impact on water quality and environmental values of the above analysis will be presented in Section VI, Evaluation of Potential for Eutrophication.

For comparison of computed and observed values, the highest concentrations for constituents samples in Dillon Reservoir and at the Blue River Outlet and Roberts Tunnel are presented in Table 15.

TABLE 15. Comparison of Observed and Computed Values for Dillon Reservoir

	TKN	$NO_2 + NO_3$	Total N	PO_4 as P
Observed Values	0.26 mg/l	0.034 mg/l	0.294 mg/l	0.11 mg/l
Computed Values	0.276 mg/l	0.094 mg/l	0.370 mg/l	0.115 mg/l

The accuracy of the computed values seems quite high with the exception of the computed values for nitrates. This could possibly be explained by a portion of the nitrates being taken up by algae and measured in the organic form rather than the inorganic form. The accuracy of the computed values also seem significantly high considering the accuracy with which the domestic waste discharges are known. This may partially be explained by the fact that under current conditions, the domestic waste loadings are only a fraction of the background waste loadings for the majority of constituents, except for nitrates which is approximately equal to the background loading, as shown in Figure 13. Note that for proposed waste loadings, the background waste loading of nitrates will become small in relation to domestic waste discharges.

2. Solution for Proposed Loadings (Completely Mixed Analysis)

The resultant equilibrium concentrations computed by the completely mixed analysis under the waste loadings from the proposed treatment plants is presented in Tables 16 and 17. The waste loadings from the treatment plants and background loadings are shown in Tables 6, 9 and 10.

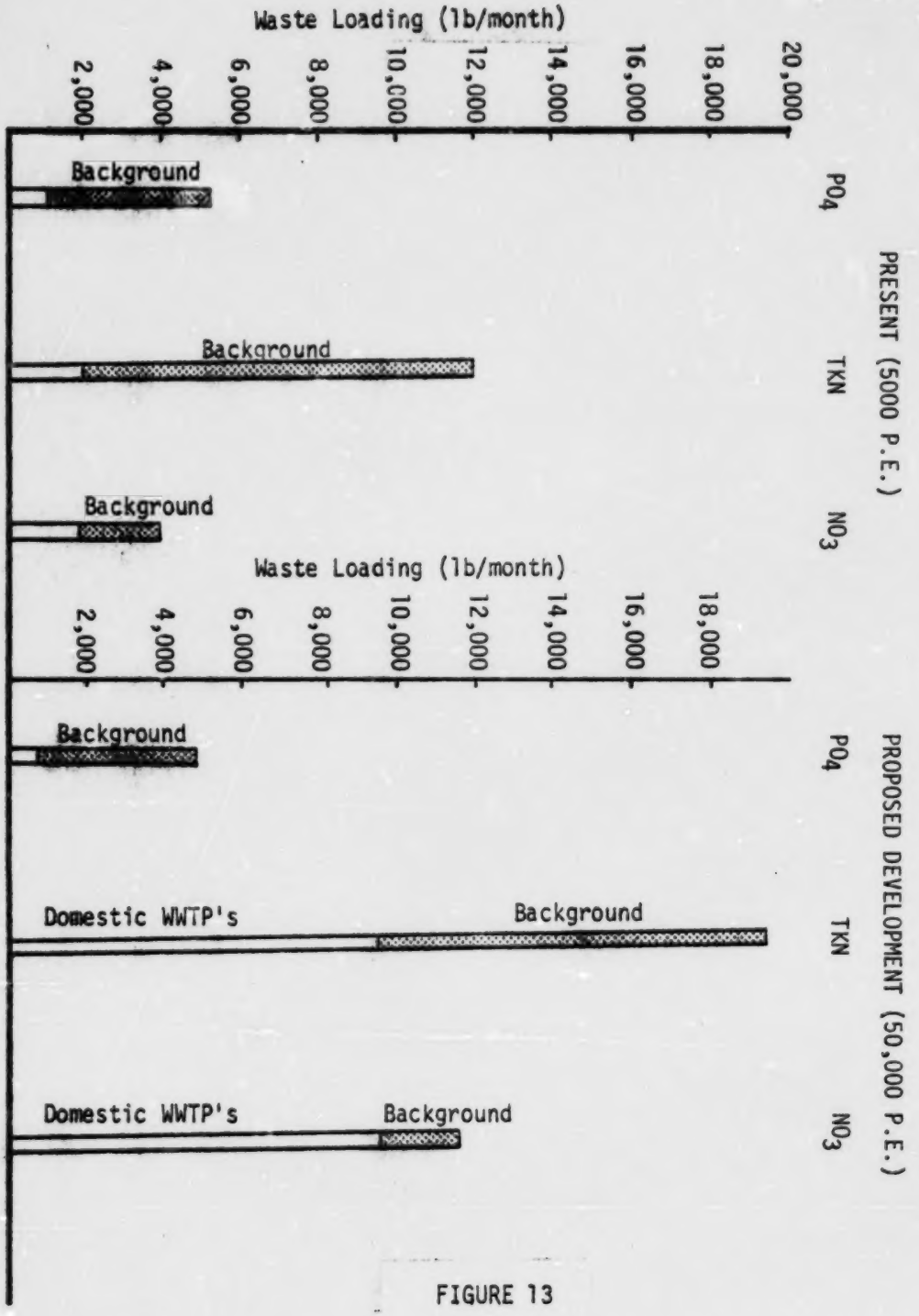


FIGURE 13

DILLON RESERVOIR
COMPARISON OF BACKGROUND
LOADINGS TO TREATMENT PLANT LOADING
AT PRESENT AND FUTURE LEVELS

a. Dillon Reservoir

TABLE 16. Completely Mixed Concentrations in Dillon Reservoir Under Proposed Loadings

	TKN	$NO_2 + NO_3$	Total Nitrogen	PO_4 as P
Concentration	0.73 mg/l	0.547 mg/l	1.28 mg/l	0.104 mg/l

A substantial increase in all nutrient concentrations except phosphates in Dillon Reservoir could be anticipated under the proposed development of treatment plants. The loadings of phosphorous could be kept essentially at their present level (largely background) through the implementation of the county standard of 95% phosphate removal.

b. Green Mountain Reservoir

TABLE 17. Completely Mixed Concentrations in Green Mountain Reservoir Under Proposed Loadings

	TKN	$NO_2 + NO_3$	Total Nitrogen	PO_4 as P
Concentration	0.408 mg/l	0.365 mg/l	0.773	0.10 mg/l

3. Solution for Ultimate Loadings (Completely Mixed Analysis)

The calculated equilibrium concentrations for Dillon and Green Mountain Reservoirs under the ultimate level of development, assuming current standards are met, are projected in Tables 18 and 19. The waste loadings from treatment plants and background loadings are presented in Tables 6, 11, and 12.

a. Dillon Reservoir

TABLE 18. Completely Mixed Concentrations in Dillon Reservoir Under Ultimate Loadings

	TKN	$NO_2 + NO_3$	Total Nitrogen	PO_4 as P
Concentration	1.23 mg/l	1.05 mg/l	2.28 mg/l	0.113 mg/l

b. Green Mountain Reservoir

TABLE 19. Completely Mixed Concentrations in Green Mountain Reservoir Under Ultimate Loadings

	TKN	$NO_2 + NO_3$	Total Nitrogen	PO_4 as P
Concentration	1.09 mg/l	1.09 mg/l	2.18 mg/l	0.11 mg/l

B. Thermal Stratification Analysis

A more refined approach to resultant water quality from waste discharges to reservoirs is to include the effect of thermal stratification and variations in inflow, outflow quantities and location of withdrawals from the reservoir throughout the year. The changing thermal structure within the reservoir has a dominant effect on the detention time which is related to the internal flow characteristics of the reservoir. In thermally stratified reservoirs, vertical motions are inhibited and the routing of inflowing and outflowing water of varying quality throughout the year is determined by the thermal regime of the reservoir.

Basically, a thermally stratified reservoir is characterized by temperature within the reservoir being a function of time and depth.(Figure 11). The temperature of the inflowing water or waste source relative to the temperature of the reservoir at any time determines the location to which the inflowing water will be allocated. If the inflowing water is warmer (therefore less dense) than the water at the surface of the reservoir, it will

enter and flow along the surface of the reservoir. If the inflowing water is colder than any of the water within the reservoir, it will flow along the bottom until it reaches the deepest portion of the reservoir. If the inflowing water is at some intermediate temperature, it will flow along the bottom until it reaches an elevation within the reservoir corresponding to its own density level, at which point it will begin to flow horizontally.

Because of the changing temperature field of the reservoir, any pollutant or water quality parameter contained in the inflowing water will be allocated to different portions of the reservoir, depending on the temperature of the inflowing water and the temperature of any portion of the reservoir at that time.

1. Qualitative analysis of Effect of Thermal Stratification on Water Quality

Qualitatively, thermal stratification of Dillon Reservoir would effect the retention time of various elements of water and therefore the resulting water quality in the reservoir in the following manner.

a. Winter Months (January 1-March 31)

Inflowing water temperature during the winter months is approximately equal to the temperature of the nearly completely mixed reservoir and therefore inflowing water is not allocated to any specific level of the reservoir (Figure 14). Quantities of runoff are at an annual low, while waste discharges to streams are at a maximum (Figure 14). This results in water with high concentrations

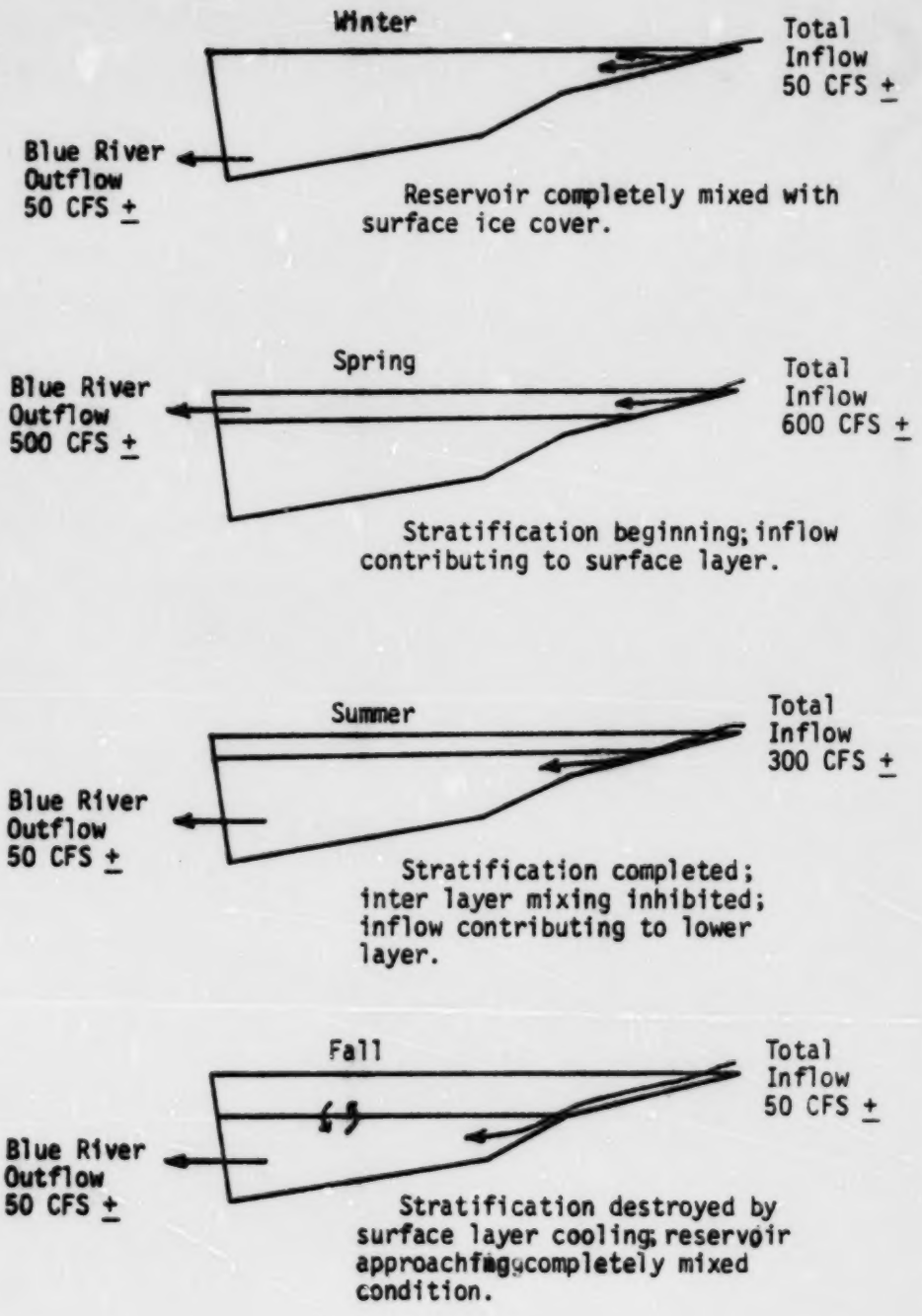

Winter
Total Inflow 50 CFS ±
Blue River Outflow 50 CFS ±
Reservoir completely mixed with surface ice cover.
Spring
Blue River Outflow 500 CFS ±
Total Inflow 600 CFS ±
Stratification beginning; inflow contributing to surface layer.
Summer
Total Inflow 300 CFS ±
Blue River Outflow 50 CFS ±
Stratification completed; inter layer mixing inhibited; inflow contributing to lower layer.
Fall
Total Inflow 50 CFS ±
Blue River Outflow 50 CFS ±
Stratification destroyed by surface layer cooling; reservoir approaching completely mixed condition.

FIGURE 14. Yearly Cycle of Stratification in Dillon Reservoir

of nutrients and other pollutants entering the reservoir and being distributed throughout all levels of the reservoir. Stratification during the winter months is not well defined and vertical mixing is not completely eliminated as during the summer months. Outflows from the reservoir tend to be minimal during this period, from both the Blue River Outlet and Roberts Tunnel Outlet. This period of time approximates the completely mixed reservoir analysis with concentrations approaching the completely mixed concentrations.

b. Spring Months (April 1-June 30)

During the spring months the temperature of the inflowing water will rise faster than that of any portion of the reservoir will contribute to a surface layer flow which would not interact to a great extent with the remainder of the reservoir. Inflowing water quality is generally highest during the spring months since stream flow is at a peak, and waste discharges are at a minimum (Figures 12 and 15). The reservoir generally reaches capacity during this time and water is discharged in large quantities through the morningglory spillway at the surface of the reservoir (Figure 16). The resultant effect of this pattern is that a large quantity of high quality water is discharged from

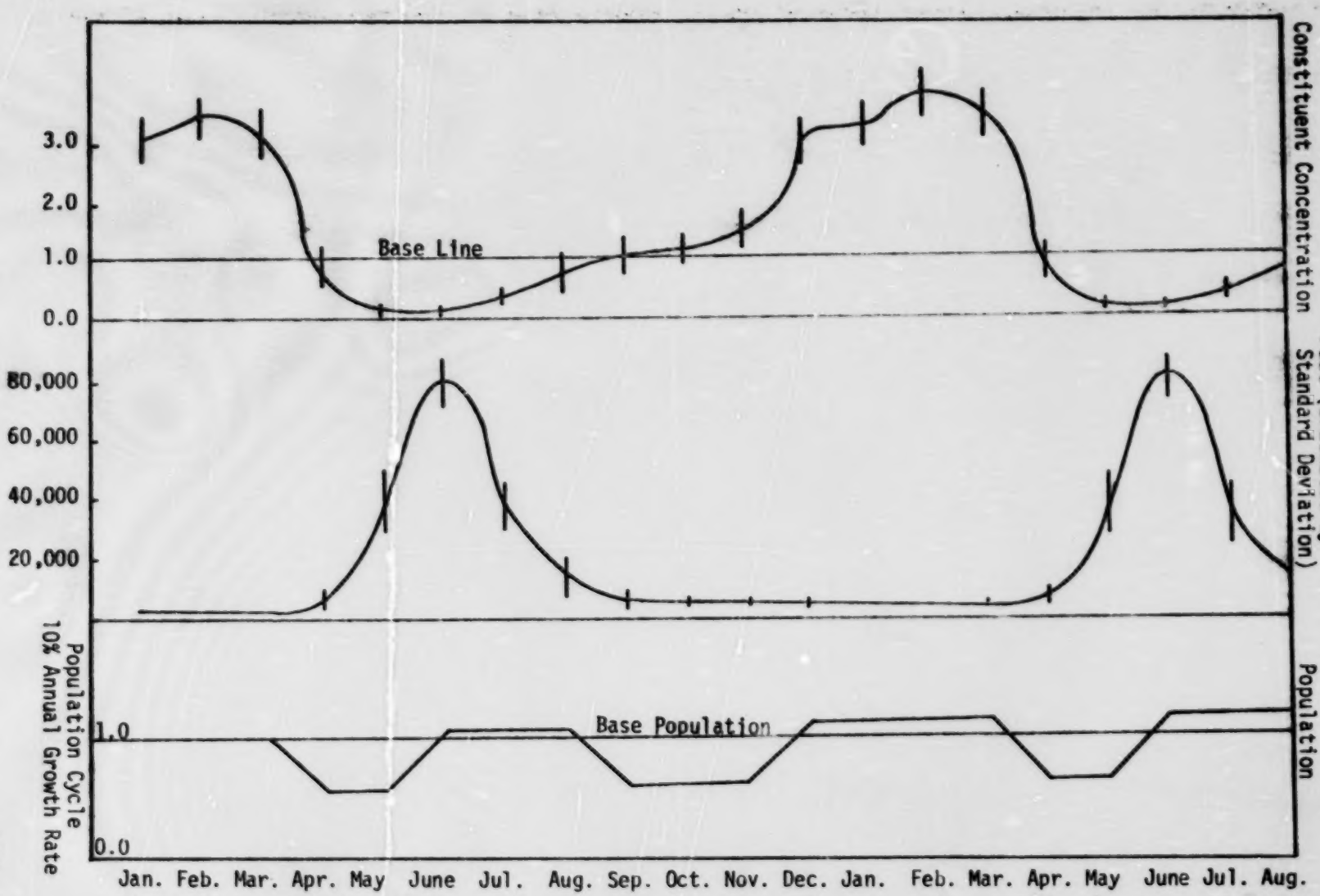


FIGURE 15. Yearly Variation in Waste Loadings and Concentrations in Streams

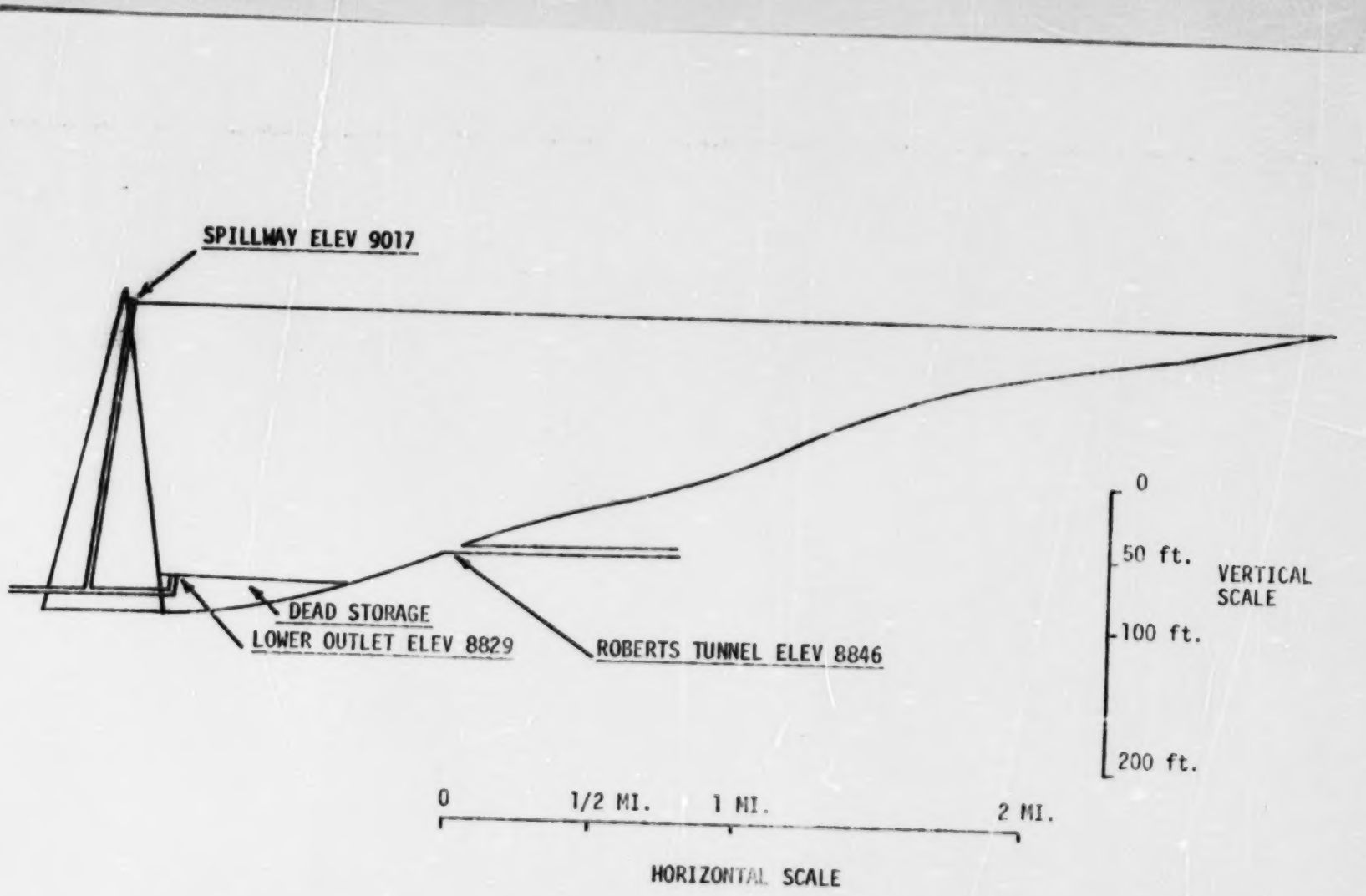


FIGURE 16. Cross Section of Dillon Reservoir

the reservoir, while the majority of the nutrients and pollutants that were discharged during the winter months continue to be stored within the reservoir.

c. Summer Months (July 1-Sept. 30)

As the summer develops, water temperatures at the surface of the reservoir continue to rise and exceed the temperature of the inflowing water. Incoming water is allocated to a level somewhere between the lower reservoir levels and the surface level. Quantities of inflowing water continue to be moderately high (Figure 15) throughout the summer, while waste discharges reach their second seasonal peak of the year (Figure 12), resulting in moderately high quality water entering the reservoir, (Figure 15). Temperature stratification becomes well developed during the summer months, inhibiting vertical motion of water from one elevation of the reservoir to another elevation. Withdrawals from the reservoir will exceed the inflows during these months, with all of the outflow taken from the lower outlets to the Blue River and Roberts Tunnel. The net result from this pattern of waste inflows and outflows is that withdrawals from the hypolimnium (the nutrient sink) will somewhat deplete potential nutrient buildups from other seasons of the year.

d. Fall Months (October 1-December 31)

As air temperatures drop rapidly in the fall, the surface water temperature drops dramatically and therefore becomes more dense than the underlying water. This causes the phenomena which is referred to as the fall overturn. Figure 10 shows that temperatures throughout the reservoir become nearly uniform throughout the more than 200 feet of

depth. This indicates that a nearly complete mixing of the reservoir is achieved by this process. The result of this phenomena is that the nutrients stored in certain elements of the reservoir during other seasons of the year are distributed uniformly throughout the reservoir, thereby raising the concentration of the entire reservoir.

The processes occurring throughout the seasons will be repeated in subsequent years resulting in increasing concentrations of nutrients and other pollutants until an equilibrium concentration is reached. Variations in water quality in certain elevations of the reservoir during certain seasons will also continue in subsequent years, while the overall trend will be towards increased average concentrations approaching the equilibrium values of the completely mixed analysis.

2. Quantitative Analysis of Effect of Thermal Stratification on Water Quality in Dillon Reservoir

Since the time and elevation variance of water quality parameters is important in evaluating the impact on the uses of water resources, an attempt was made to simulate the processes affecting water quality in Dillon Reservoir through the use of a mathematical model.

However, adequate data on the variation of nutrients, BOD, and dissolved oxygen concentrations, with time and depth, are not available to calibrate the coefficients which describe the physical and biological phenomena that determine the coefficients.

A description of the modeling approach and mathematical formulations is presented in Appendix A. It is anticipated that as the knowledge of the effect of waste discharge effects is increased through monitoring of the reservoir, that the model could be used to predict more precisely the nutrient, BOD and dissolved oxygen concentrations under increased waste loadings.

VI. EVALUATION OF POTENTIAL FOR EUTROPHICATION

In the past, the vast majority of effort in water pollution control has been directed at removing the biochemical oxygen demanding organic material from waste streams. Consequently, the state of the art in sewage treatment processes has developed around the stabilization of organic matter before discharge to the receiving water. Unfortunately, the oxidized forms of nitrogen, phosphorous and other materials discharged in the waste stream have a significant potential for stimulating algae growth beyond acceptable levels. The applicability and adequacy of the existing effluent requirements established by the County, under the increased waste loadings from point sources will be evaluated in this section. Also, if it is determined that existing technology is not adequate to provide the level of treatment required, land use controls to limit the background and point waste loadings of nutrients will also be considered.

The existing county standards require 95% removal of phosphates by all newly constructed sewage treatment plants discharging to the waters of the county. As shown in Section V, this measure would be adequate to maintain the concentrations of phosphates in Dillon Reservoir at their present levels until a population equivalent of 95,000 is reached. In assessing the environmental impact of the waste discharges it is necessary to quantitatively analyze if this measure alone will be sufficient to protect the waters of Dillon and Green Mountain Reservoirs from potential eutrophication or excessive algal growth.

A. Phytoplankton Growth Kinetics and Influences on Water Quality

The quality of natural waters can be markedly influenced by the growth and distribution of phytoplankton. The quality of a body of

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water can be adversely affected if the population of phytoplankton becomes so large as to interfere with either the established uses of the water or the higher aquatic life forms. High concentrations of algal biomass causes large diurnal variations in dissolved oxygen, whichmmay result in loss of fish and other higher aquatic organisms. The buildup of algae in high concentrations in bays and inlets causes aesthetic problems, especially when they decay or either settle to the bottom or accumulate in windrows on the shoreline. High concentrations of some algae may release toxins when they die and produce fish kills. High concentrations of nutrients and phytoplankton can cause taste and odor problems in municipal water supplies, as well as increase treatment costs due to clogging of filters in water treatment plants.

In a balanced lake ecology, the input of nutrients and losses from the are balanced by nutrient losses to the food chain and direct losses from the system. When this equilibrium is disturbed as a result of man's increasing numbers and concentrations and activities relating to enrichment of natural waters, the result is an overfertilization of the waters, or a process known as cultural eutrophication.

Generally, the management of water resources subjected to potential eutrophication because of waste discharges has been largely subjective, with effluent requirements established without full examination of the effect of nutrient removal programs. A qualitative methodology for the prediction of the effects of nutrient loadings is addressed in this analysis. Because of the complicated biological and physical phenomena which influence the

growth and distribution of phytoplankton, several simplifying assumptions have been made in this analysis.

1. Phytoplankton System Interactions

Because of the complexity of the physical and biological systems influencing phytoplankton growth and distribution, it is necessary to idealize the conceptual model of phytoplankton growth so that the result is a manageable set of dependent subsystems and their interrelations. The model as developed by Ditoro[1] is formulated on the basis of three primary systems. The phytoplankton population whose behavior is the subject of concern; the herbivorous zooplankton, which are the predators of the phytoplankton; and the nutrient system, which consists primarily of inorganic substances and are required by the phytoplankton for growth. These systems are affected both by interactions within the three systems as well as by external environmental values, including temperature, advective and dispersive fluid flow which are the primary mass transport mechanisms, and solar radiation, the energy source for the photosynthetic growth of the phytoplankton. It should be noted that the only variables affecting algae growth which can be practicably controlled are the inputs to the nutrient

1. Ditoro, Dominick M. "A Dynamic Model of Phytoplankton Population in Natural Waters," Manhattan College, Bronx, N.Y., June 1970.

system. The basic principle to be applied to this conceptual model is that of conservation of mass; i.e. the interactions within the system can be defined by the transfer and transport nutrient mass.

a. Phytoplankton Growth Rate

The growth of phytoplankton is dependent on the availability of nutrients and external environmental conditions such as temperature and light intensity. The relative growth response of phytoplankton under varying temperatures is shown in Figure 17. An optimum level of light intensity at one level of the reservoir is assumed to be provided during the critical summer period. This optimum light intensity has been shown to be approximately 2000 foot candles.

The availability of nutrients is the controlling factor in determining the phytoplankton growth rate. Monod growth kinetics theorize that the growth rate of phytoplankton proceeds at the saturated rate for the temperature and light conditions present, at an adequate level of substrate concentration. However, at low nutrient concentrations the growth rate becomes linearly proportional to substrate concentrations. Thus for a nutrient with concentrations, N, the factor by which the saturated growth rate is reduced is $\frac{N}{Km+N}$. The constant, Km, is called the Michaelis constant and represents the concentration at which the growth rate is half of the saturated growth rate.

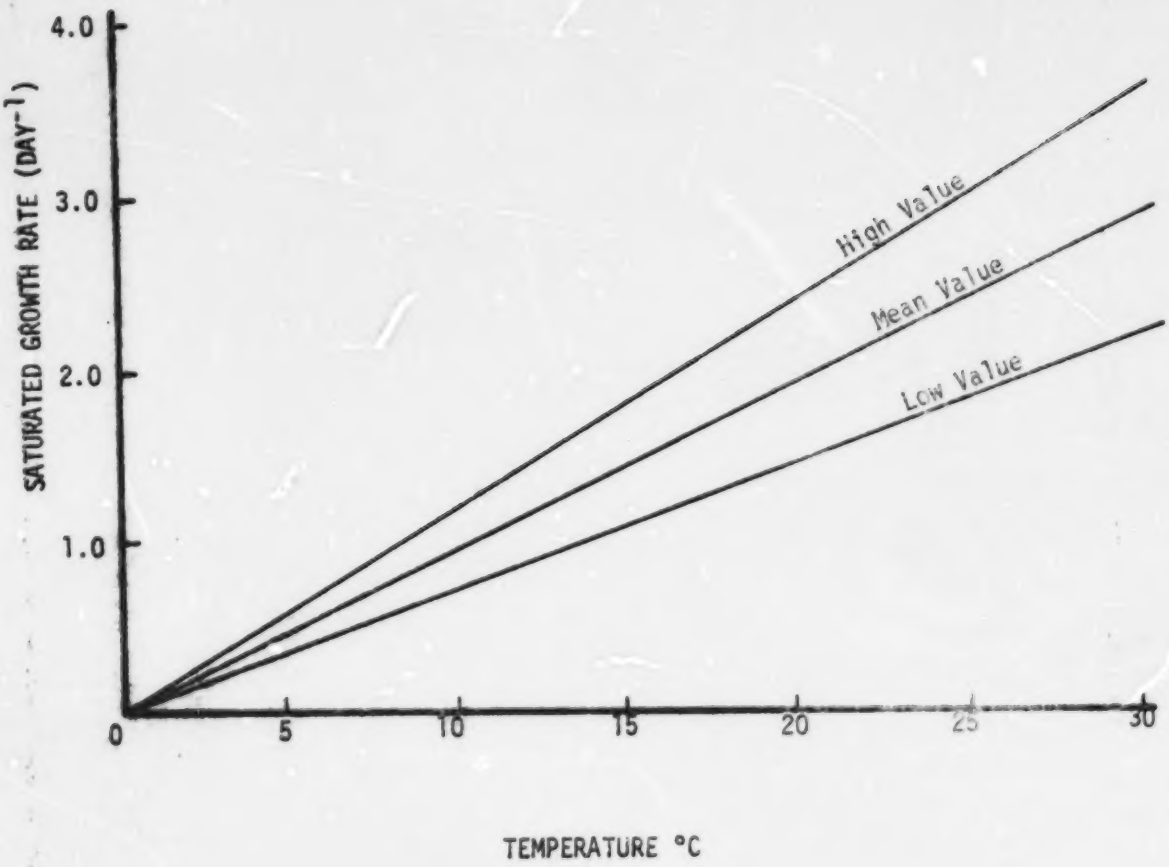

FIGURE 17. Phytoplankton Growth Rate as a Function of Temperature

b. Phytoplankton Death Rate

The death of phytoplankton is determined by three phenomena, some of which are interactive with the growth rate of phytoplankton. The death rate can be described as a function of endogenous respiration, grazing by herbivorous zooplankton, and the rate of sinking of phytoplankton to lower levels in the reservoir.

Endogenous respiration is the reverse process of photosynthesis; phytoplankton biomass population is depleted in this process. The rate of endogenous respiration has been shown to be a linear function of temperature, that is: Respiration Rate = K_2T. The death rate of algal cells after a large bloom is of particular interest since this determines a large proportion of the dissolved oxygen deficit, which may result in fish kills.

B. Evaluation of Eutrophication Potential

The potential for man induced eutrophication or nuisance algae blooms in either Dillon or Green Mountain Reservoirs is largely a function of whether or not the phytoplankton growth rate is balanced by the phytoplankton death rate at concentrations of nutrients which would result from man's activities. There are many parameters which affect both of these rates which are not yet clearly defined for either of the reservoirs.

1. Algae Growth Stimulation Due to Increased Nutrient Concentrations

As part of the study, Dillon and Green Mountain Reservoirs were analyzed for the potential to stimulate algae growth under current nutrient levels based upon available data. Projections of future nutrient loadings and resultant nutrient concentrations in the reservoir were used to project the increased stimulation of algae growth due to the increased loadings.

The three external environmental variables for the summer months are well defined. Light intensity and temperature in the hypolimnion both are in the range of being optimum during at least one month of the summer. An optimum temperature is considered to be 20°C, with temperatures in Dillon Reservoir averaging near 17°C for the month of August.

Using mean values for the Michaelis Constant, Km, the growth reduction factor for each of the three levels of development was analyzed. The figures presented in Table 20 are the percent reduction from optimum conditions, using the Michaelis-Menton expression.

TABLE 20. Percent Reduction Factor for Algal Growth in Dillon Reservoir at Three Levels of Development

	Level of Development		
Element	Current Level	Proposed Level	Ultimate Level
(1) NO_3 as N	34% of Optimum Concentration @ .034 mg/l NO_3	89% of Optimum Concentration @ 0.547 mg/l NO_3	95% of Optimum Concentration @ 1.05 mg/l NO_3
(2) PO_4 as P	82% of Optimum Concentration @ 0.11 mg/l PO_4	81% of Optimum Concentration @ 0.104 mg/l PO_4	82% of Optimum Concentration @ 0.113 mg/l PO_4
Composite Effect (1) x (2)	28% of Optimum Concentration	72% of Optimum Concentration	77% of Optimum Concentration

In summary, nutrient loadings to Dillon and Green Mountain Reservoirs will result in concentrations of nutrients (from the completely mixed analysis), which will provide nearly optimum conditions for algal growth. The growth stimulation potential provided by nitrates indicates that projected increases in nitrate concentrations would result in a very large increase towards the optimum nutrient concentration. Since the concentration of nutrients in the hypolimnion could be expected to increase markedly above the calculated values during the summer months when stratification occurs and environmental conditions are favorable to stimulating algal growth, this analysis is considered to be extremely conservative in estimating the potential for nuisance algae growths in the reservoir.

For comparative purposes, the Committee on Water Quality Criteria of the Federal Water Pollution Control Administration (predessor to EPA) recommends that total phosphorus concentrations not exceed 0.05 mg/l in reservoirs and that inputs to the reservoir should not markedly change the ratio and amounts of phosphorus to nitrogen occurring in the reservoir.

VII. WATER QUALITY MANAGEMENT OBJECTIVES AND ALTERNATIVES

A. Water Quality Objectives and Priorities Among Waters

Based on the preceding analysis, several alternatives are available which will protect the water quality of Dillon and Green Mountain Reservoirs and minimize the potential for eutrophication. It should be recognized that the most desirable alternative will be the one which balances costs against potential benefits from the many uses of the water resource within the Blue River Basin. Because it is difficult, if not impossible, to adequately quantify the benefits accruing to residents of the state from maintenance of water quality in Dillon and Green Mountain Reservoirs, it will not be possible to optimize the water quality management plan. However, keeping in mind that recreation is the major economic activity in Summit County and also that Dillon Reservoir will continue to serve as the principal water supply source for over a million people on the eastern slope of Colorado, the protection of this water resource cannot be overemphasized. In establishing the priorities of waters within the state which will be afforded protection from degradation, the Blue River Basin should receive a high priority.

Water quality objectives for the Blue River Basin should accordingly provide the highest degree of protection of the water resource. An initial criteria for water quality management in the Blue River Basin is to limit nutrient and pollutant loadings at their present levels until additional information on the growth stimulation factors of various nutrient and trace element levels can be established through algal assay techniques. This may allow for either

an increase or decrease in the amount of nutrients which can safely be discharged to either of the reservoirs. This objective is consistent with the requirements for including a "margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality" as called for under the Water Pollution Control Act Amendments of 1972, Section 303(a).

B. Water Quality Management Alternatives

There are several management alternatives available to meet the initial criteria for limiting nutrient and pollutant loadings to their current levels. The two basic options are to limit the amount of nutrients entering the system through point source control, or limiting the amount of nutrients through land use controls and watershed protection to reduce the background loading. In an area such as Summit County where there is a relatively small percentage of privately owned developable land, the implementation of land use controls would obviously have an effect on the amount of waste generated by point sources in the basin, such that the second option cannot be implemented without affecting point source loadings.

Any alternative for water quality management which is chosen as a control strategy should include consideration for removal of residuals generated (sludge processing, etc.) such that nutrients and other contaminants cannot re-enter the hydrologic system by another route. For example, current practices at the Summit County No. 1 Plant are such that phosphorous is removed from the effluent to a high degree but sludge handling processes are unplanned and

result in nearly complete re-introduction of this component before the effluent reaches Dillon Reservoir. Sludge handling and disposal should be planned such that residuals are completely eliminated from the hydrologic system. Another example of planning for elimination of residuals generated through treatment processes would be in the consideration of the amount of ammonia which would re-enter the hydrologic system through atmospheric fallout if ammonia stripping were implemented.

1. Point Source Control

In order to maintain loadings to Dillon and Green Mountain Reservoirs at their current level, while allowing for expansion of wastewater treatment plants to meet projected demands, it would be necessary to either require further advanced waste treatment or export wastes out of the basin. Exportation of wastes completely out of the basin was eliminated as a practical alternative because of the distance (approximately 30 miles) from the major developments in the Dillon Reservoir area to Green Mountain Reservoir.

The projected levels of reduction which would be required to implement this alternative at proposed and ultimate development are presented in Tables 21 and 22.

TABLE 21. Required Point Source Additional Reductions at Proposed Level of Development

Element	Background Loading (lb/day)	Proposed Point Source Loading (lb/day)	Allowable Loading (lb/day)	Additional Load Reduction Required (lb/day)	Percent Reduction Required for Point Sources (%)
TKN	345	650	408	587	90%
$NO_2 + NO_3$	70	650	133	587	90%
Total Nitrogen	415	1300	541	1174	90%
PO_4 as P	138	26	188	-	No Additional
BOD_5	1725	218	1788	155	

TABLE 22. Required Point Source Reductions at Ultimate Development Level

Element	Background Loading (lb/day)	Proposed Point Source Loading (lb/day)	Allowable Loading (lb/day)	Load Reduction Required (lb/day)	Percent Reduction Required For Point Sources (%)
TKN	345	1300	408	1237	95.5
$NO_2 + NO_3$	70	1300	133	1237	95.5
Total Nitrogen	415	2600	541	2474	95.5
PO_4 as P	138	33.0	188	-	No Additional
BOD_5	1725	435	1788	372	

There are many alternative configurations for wastewater treatment systems which were considered which would effectively control point source discharges to the acceptable levels. The alternatives are listed and described below.

Alternative 1

This alternative consists of the construction of secondary waste treatment followed by phosphorous removal, nitrification and nitrogen removal with plants at the following locations (See Figure 18-1):

*(1) Ten Mile Creek (Ten Mile Creek Drainage Basin)

*(2) Breckenridge (Upper Blue River Drainage above Dillon Reservoir)

*(3) Snake River (Snake River Drainage Basin)

**(4) Dillon - Silverthorne

**(5) Rock Creek (Lower Blue River Drainage to confluence with Rock Creek)

Alternative 2

Same as alternative 1 with plants at:

*(1) Breckenridge

*(2) Snake River

**(3) Rock Creek

*(4) Ten Mile Creek

*Discharges to Dillon Reservoir or watershed of Dillon Reservoir.
**Discharges to Lower Blue River above Green Mountain Reservoir.

Alternative 3

Same as Alternative 1 with plants at:

*(1) Ten Mile Creek

*(2) Breckenridge

**(3) Dillon-Silverthorne (Includes Snake River Service Area)

**(4) Rock Creek

Alternative 4

Same as Alternative 1 with plants at:

*(1) Ten Mile Creek

*(2) Breckenridge

**(3) Rock Creek (Includes Snake River and Dillon Silverthorne Service Areas)

Alternative 5

Same as Alternative 1 with plants at:

*(1) Breckenridge

**(2) Dillon-Silverthorne (Includes Snake River and Ten Mile Creek Service Areas)

**(3) Rock Creek

Alternative 6

Same as Alternative 1 with plants at:

*(1) Breckenridge

**(2) Rock Creek (Includes Snake River, Ten Mile Creek and Dillon-Silverthorne Service Areas)

*Discharges to Dillon Reservoir or watershed of Dillon Reservoir.
**Discharges to Lower Blue River above Green Mountain Reservoir.

Alternative 7

Same as Alternative 1 with plants at:

*(1) Dillon (Includes Breckenridge, Snake River, and Ten Mile Creek Service Areas)

**(2) Rock Creek

Alternative 8

Same as Alternative 1 with plants at:

**(1) Rock Creek (Includes all service areas)

Alternative 9

This alternative consists of construction of secondary treatment plants at several locations specified below, with phosphorous removal, nitrification, and denitrification of the effluent provided at two plants, one located at Dillon-Silverthorne would treat all upstream wastes. The Rock Creek plant would give secondary and tertiary treatment to waste flows. between the Dillon-Silverthorne plant and the Rock Creek plant. Secondary plants would be constructed at:

***(1) Breckenridge

***(2) Snake River

***(3) Ten Mile Creek

**(4) Dillon-Silverthorne

**(5) Rock Creek

Alternative 10

Same as Alternative 9 with advanced waste treatment provided at one plant at Rock Creek.

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*Discharges to Dillon Reservoir.
**Discharges to Lower Blue River above Green Mountain Reservoir.
***Discharges to Lower Blue River above Green Mountain Reservoir through Dillon-Silverthorne Plant.

Alternative 11

This alternative consists of the construction of secondary treatment plants at the Ten Mile Creek and Snake River Sites with advanced waste treatment provided for the effluent from these plants at the Dillon-Silverthorne plant. The Breckenridge and Rock Creek integrated plants would be constructed to provide integrated secondary and advanced waste treatment on site.

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

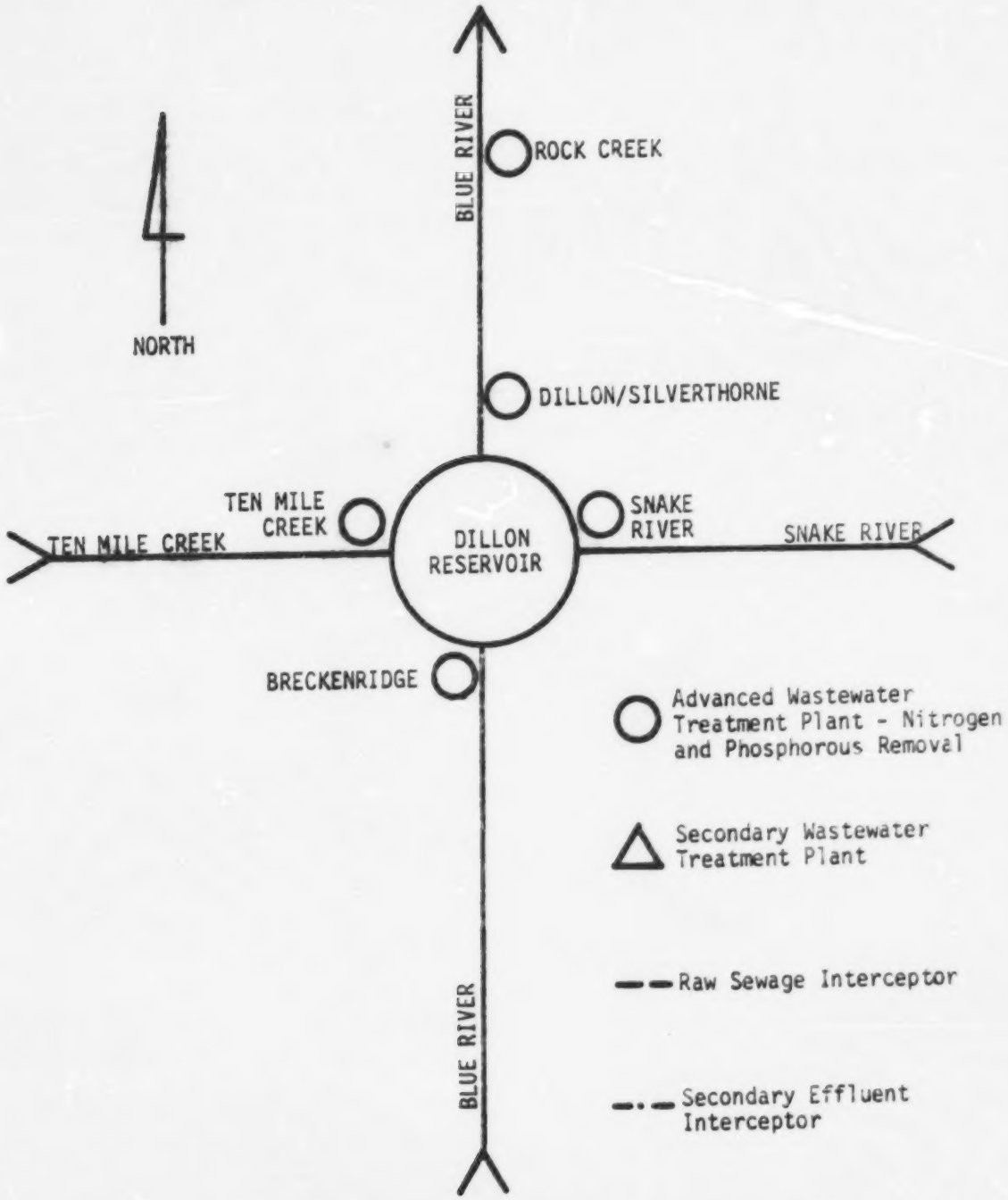

FIGURE 18-1 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #1

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

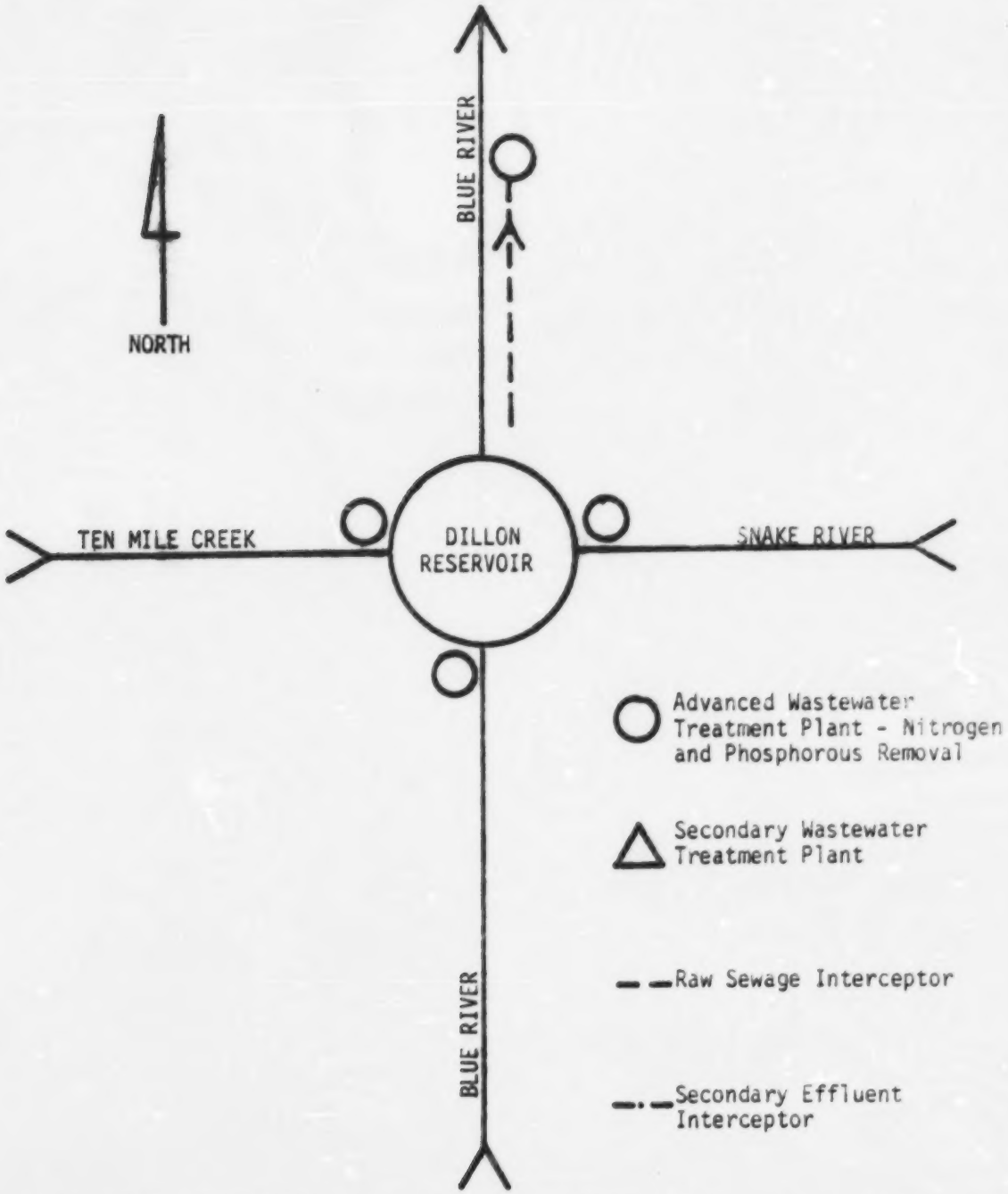

FIGURE 18-2 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #2

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

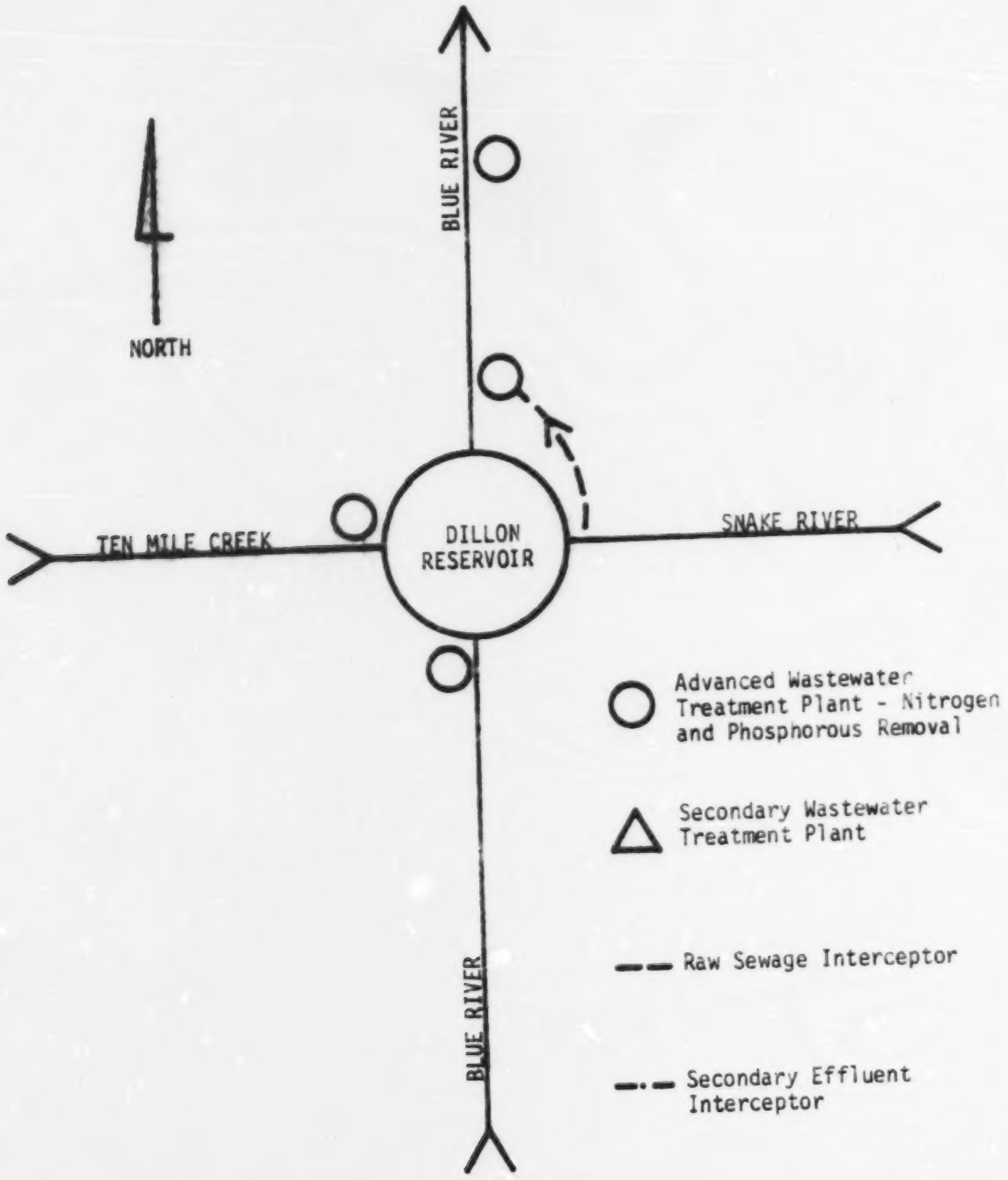

FIGURE 18-3 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #3

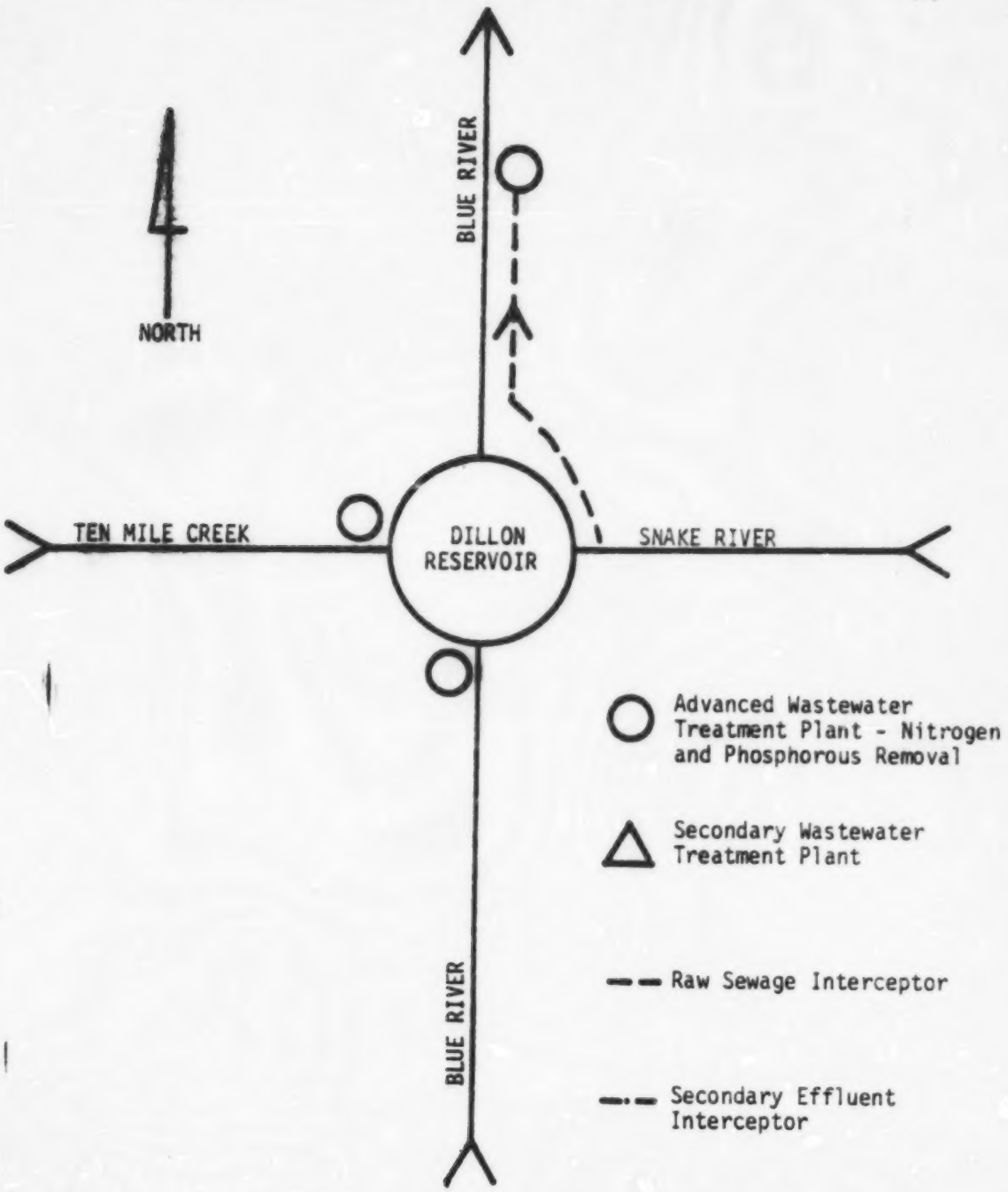

FIGURE 18-4 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #4

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

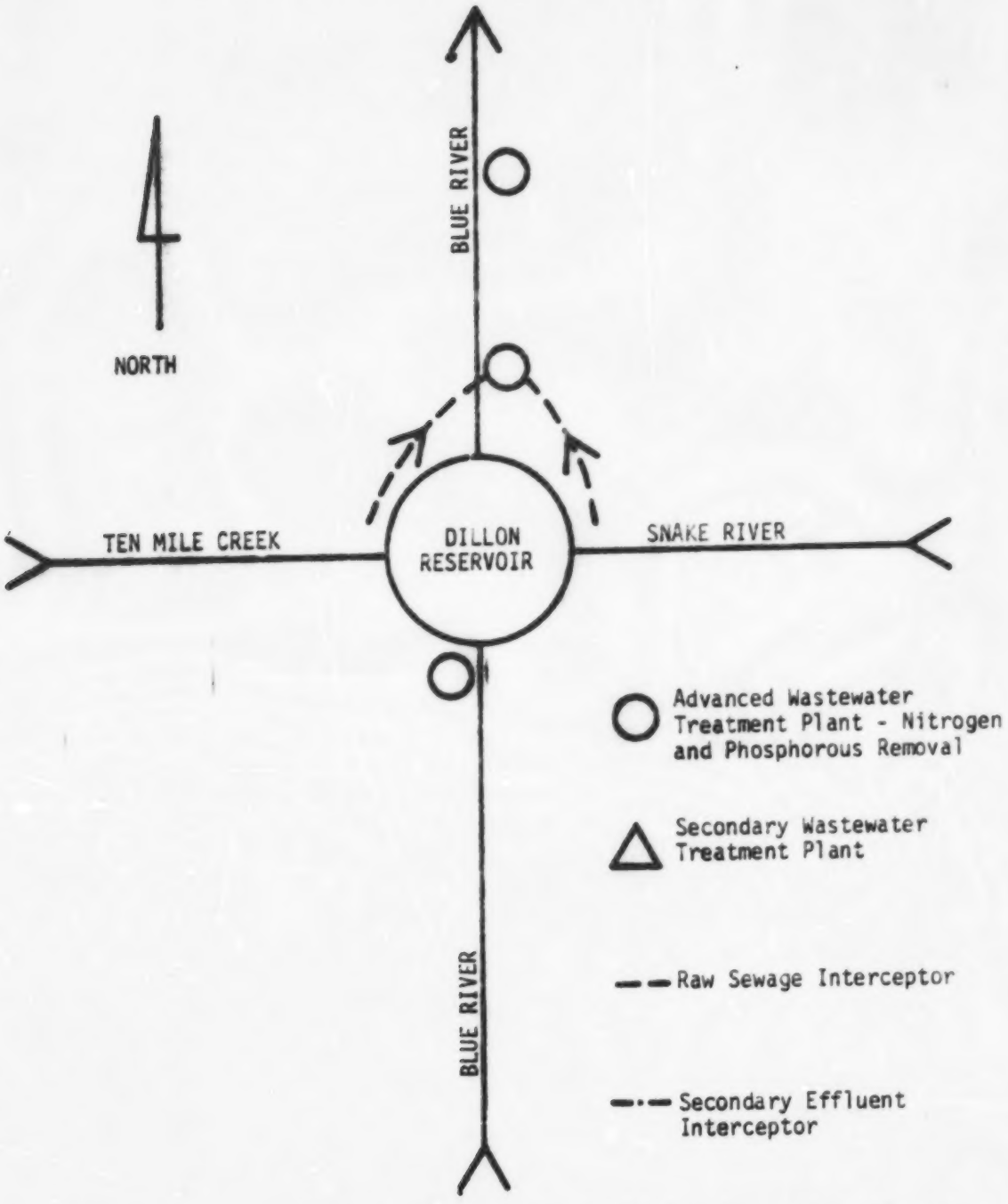

FIGURE 18-5 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #5

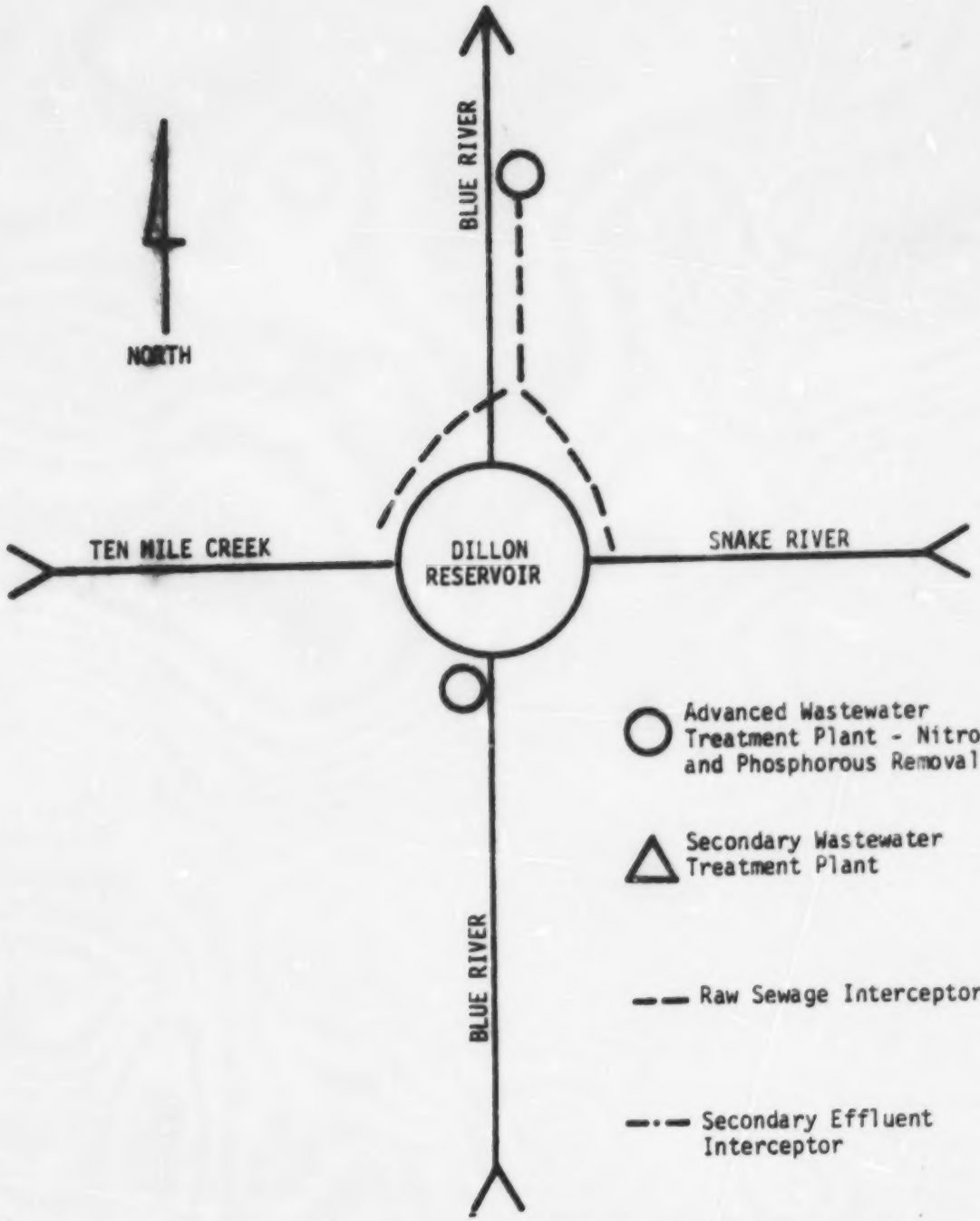

FIGURE 18-6 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #6

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

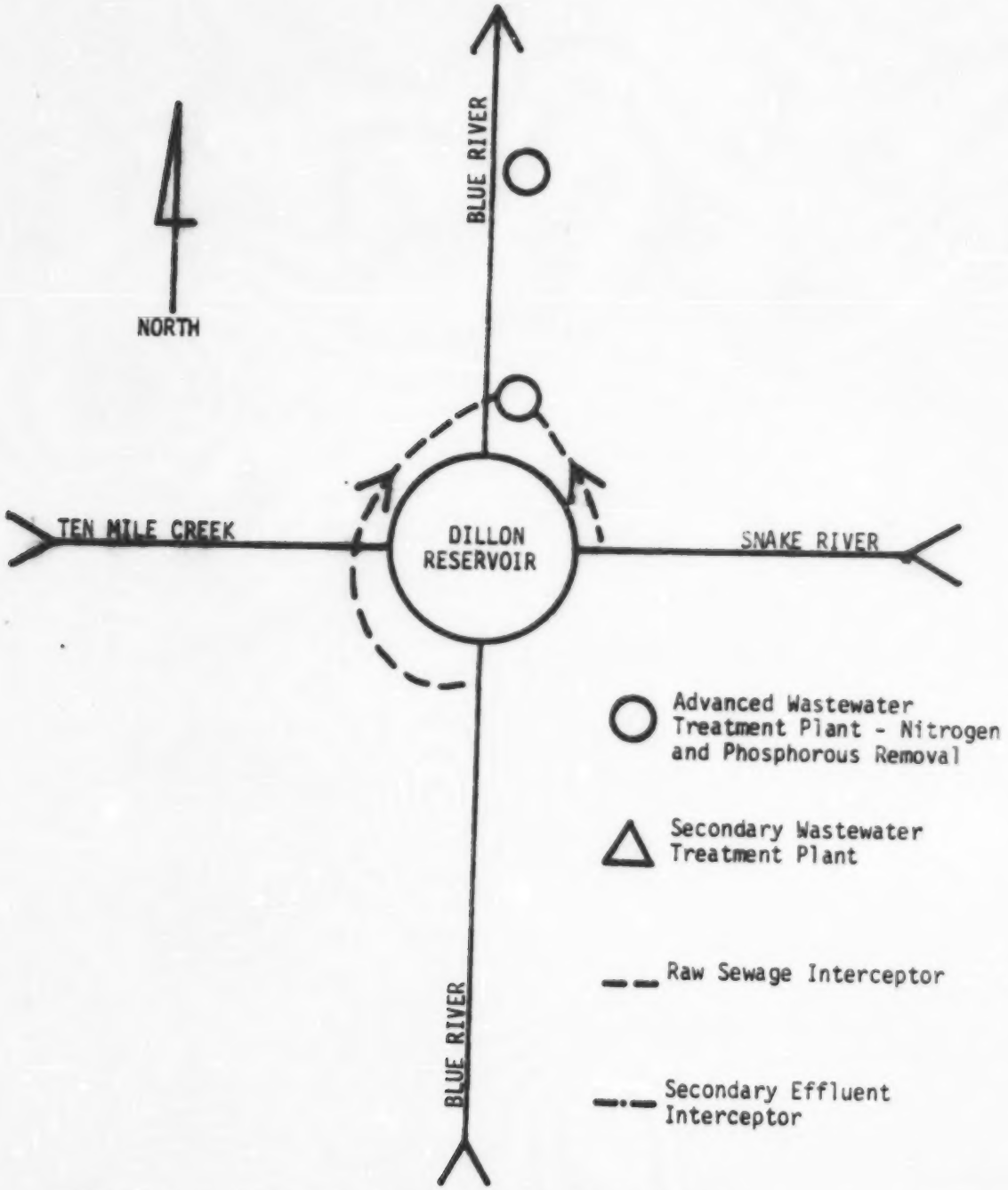

FIGURE 18-7 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #7

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

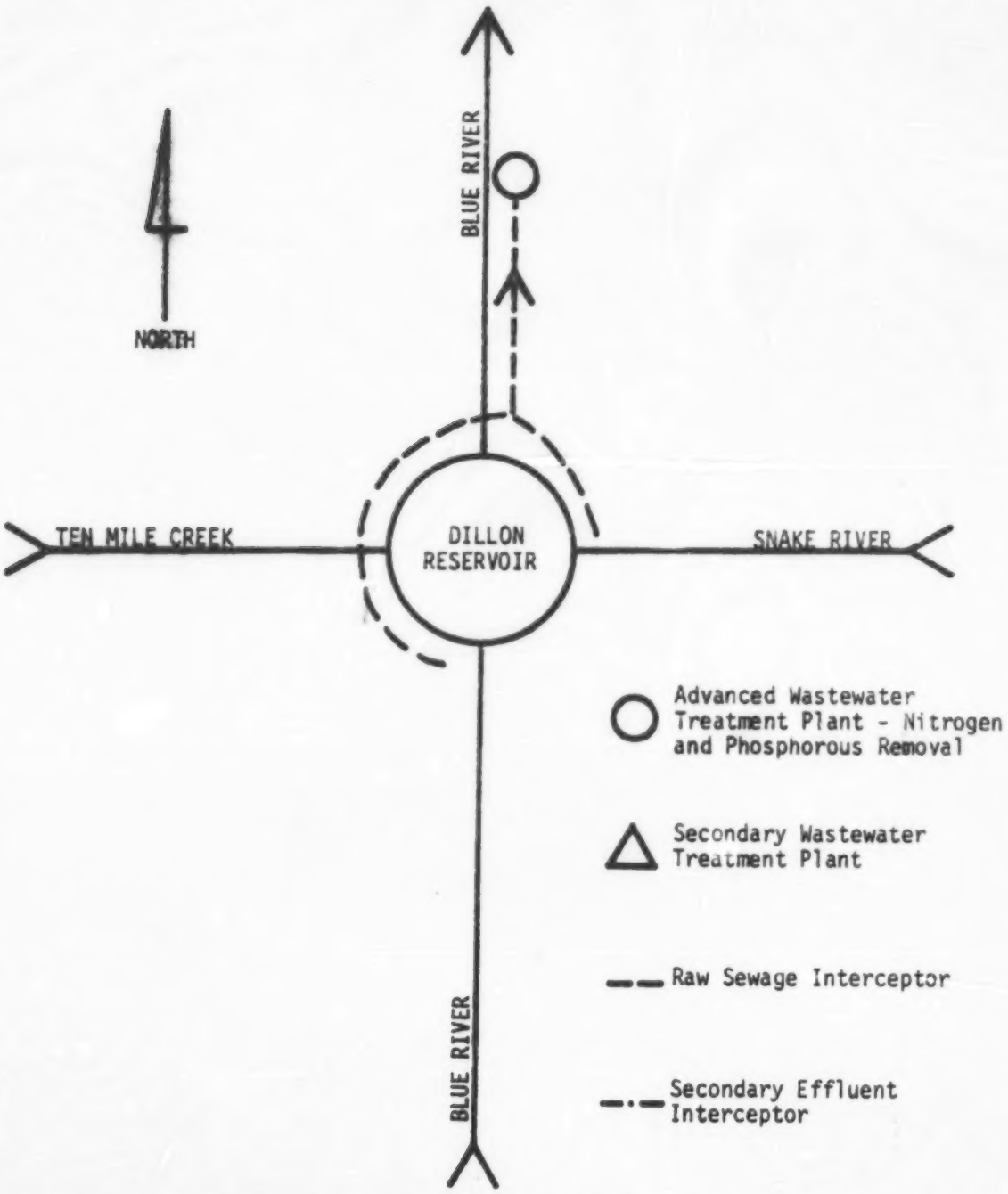

FIGURE 18-8 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #8

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

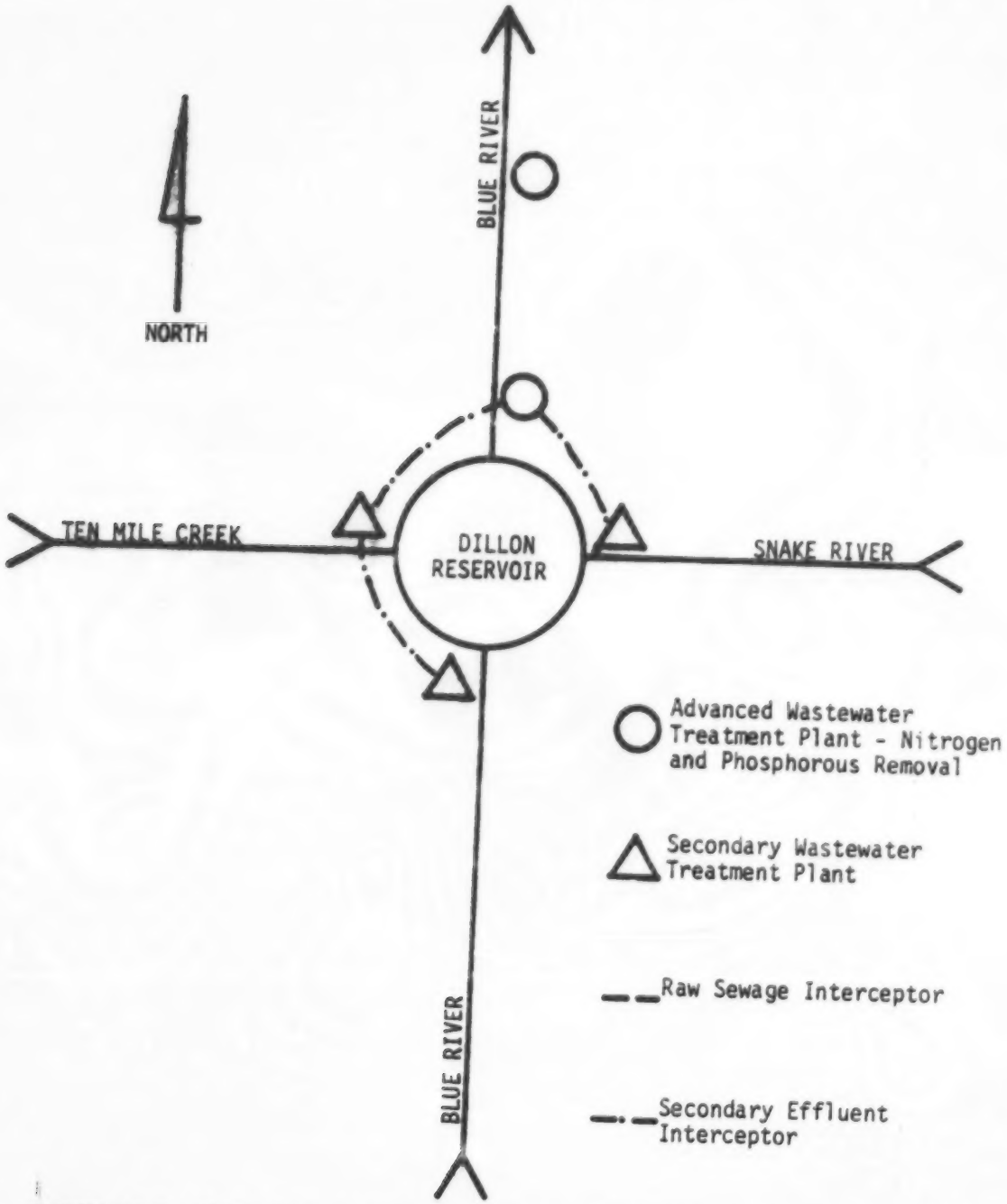

FIGURE 18-9 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #9

ALTERNATIVE TREATMENT PLANT SITE EVALUATION

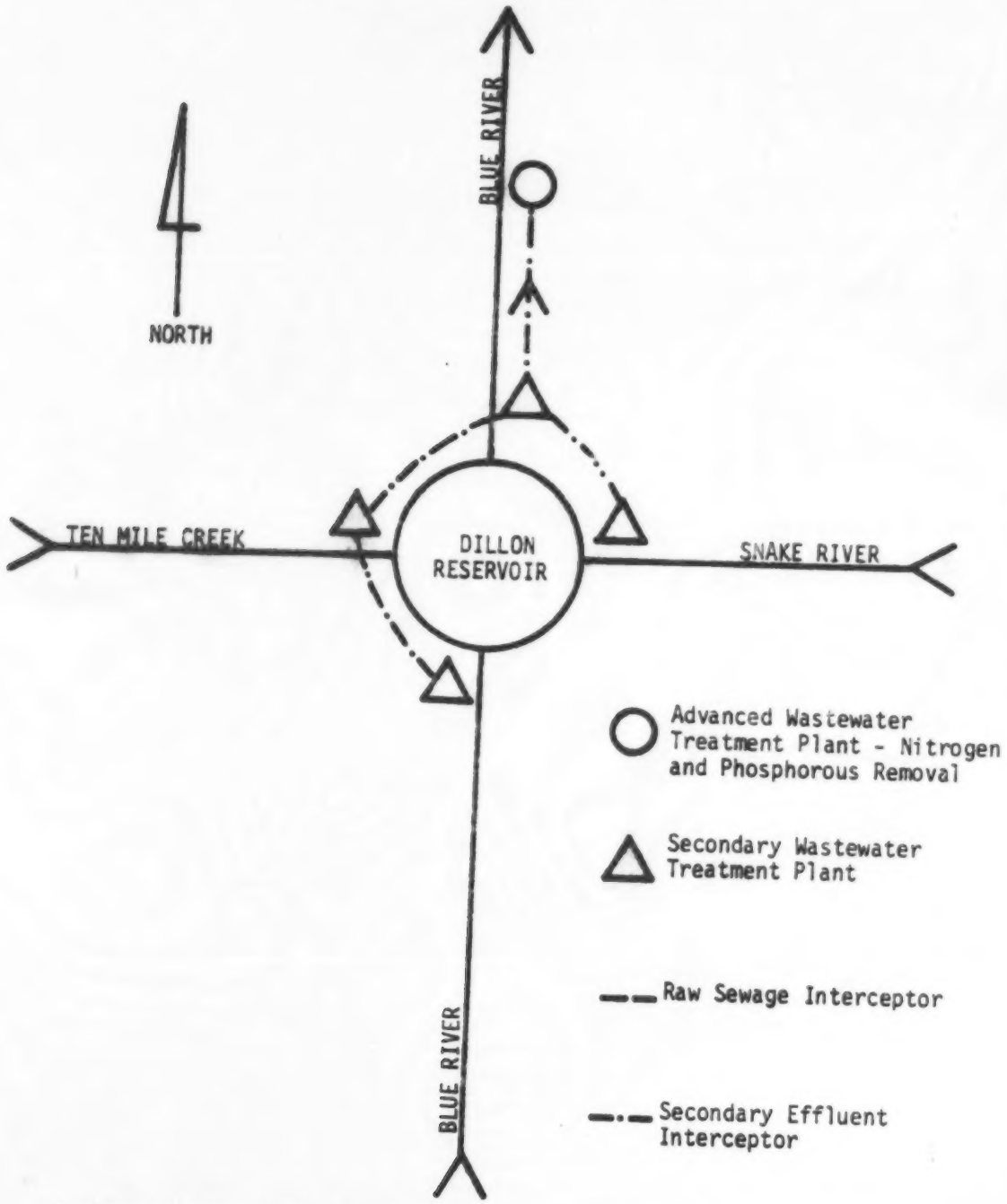

FIGURE 18-10 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #10

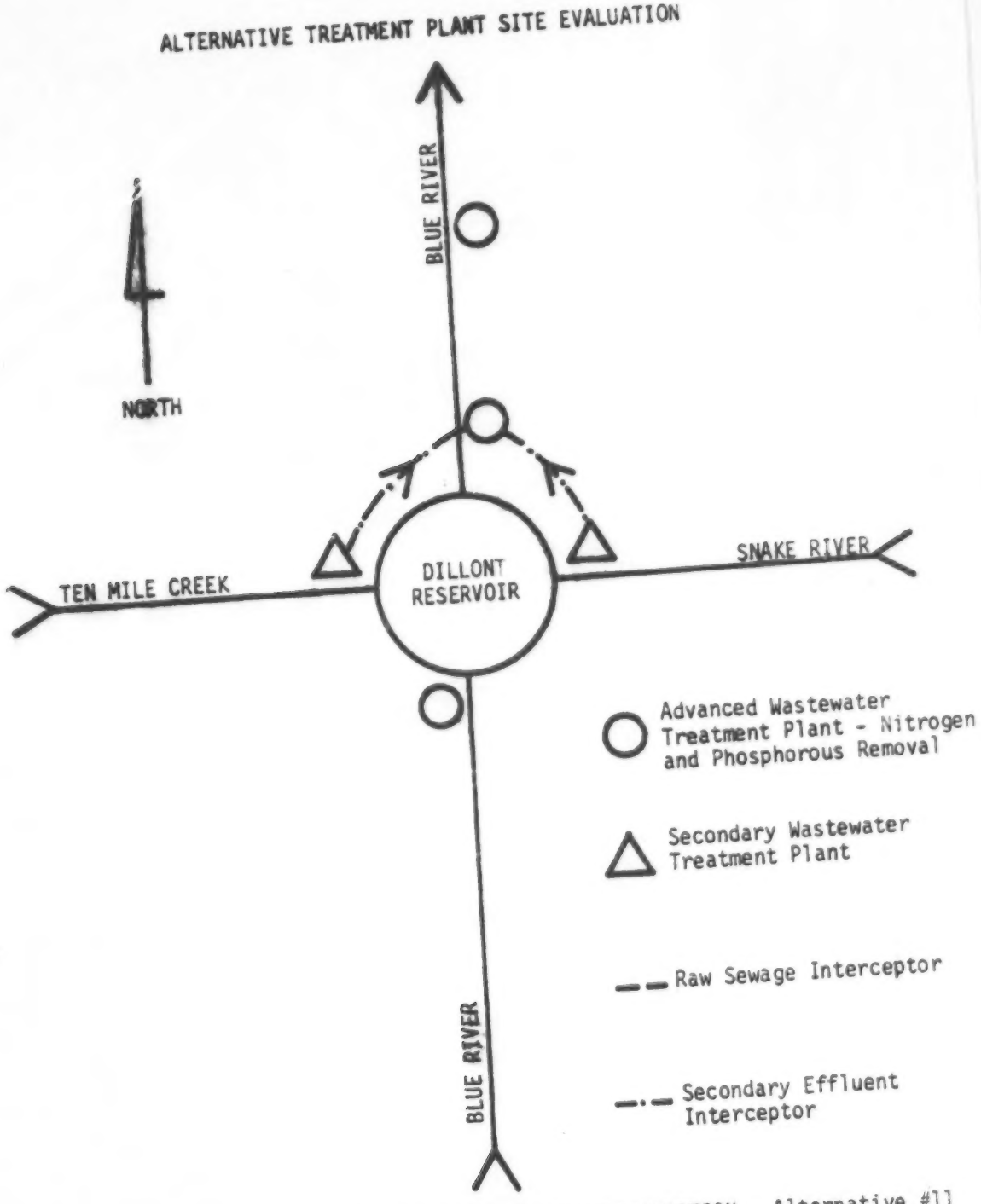

FIGURE 18-11 WASTEWATER TREATMENT PLANT CONFIGURATION - Alternative #11

2. Land Use Controls and Watershed Protection

An undisturbed or virgin watershed could be expected to produce nutrient loadings from background levels somewhere in the order of magnitude of 50% of that which is presently yielded from the Upper Blue River Basin. This does not take into consideration nutrients which enter the system adhered to soil particles and sediment carried in the bed load of streams which are not measured by conventional sampling techniques. Development of high density dwelling units, construction of roads, water and sewer lines, and changes in land use patterns of forested and grazing lands all contribute to increased nutrient yields within the watershed. Restrictions on use of land, based on slope, soil type, surficial geology and other factors influencing nutrient yields, can substantially reduce nutrient loadings with the upper limit on reductions being the natural equilibrium conditions.

Table 23 represents the level of nutrient reductions which would be required if land use controls alone were relied upon to reach water quality objectives, while allowing wastewater flows to increase as projected with no additional controls. The levels of reduction required by this alternative are beyond the level which would be expected to be produced by a virgin watershed. Land use controls alone are therefore not a viable alternative to reducing the nutrient loadings in the watershed.

TABLE 23. Required Levels of Background Reductions through Land Use Controls

Element	Existing Background Loading (lb/day)	Allowable Loading (lb/day)	Proposed Point Source Loading (lb/day)	Allowable Background Loading (lb/day)	Background Reduction Required (%)
TKN	345	408	650	63	82%
$NO_2 + NO_3$	70	133	650	63	10%
Total N	415	541	1300	126	72%
PO_4 as P	138	188	26	162	0
BOD_5	1725	1788	218	1570	9%

Keeping in mind that land use controls will affect the density and location of developments, and therefore the discharge of wastes through point sources, a balance of control through point source and background control could be achieved which would meet the water quality objectives.

From studies conducted in the Lake Tahoe area on nutrient yields from undisturbed, moderately disturbed and highly disturbed watersheds, it could be expected that land use practices that minimize the effect of man's activities would yield nutrient loadings 80% of a highly disturbed watershed. This alternative would require a reduction in density of developments and restrictions on construction clearing in areas susceptible to erosion because of soil type or slope. Selection of landfill and solid waste disposal sites would also have to minimize the possibility of leachate entering or re-entering the hydrologic system.

Based on the reduction in background loadings which could be anticipated with land use controls, the amount of reduction required through point source controls could be reduced as shown in Table 24. The point source limitations listed could be met in a variety of ways: (1) limiting population growth to levels which would produce these loadings with conventional waste treatment, or, (2) limiting population growth to the level which would produce these loadings with some intermediate level of advanced waste treatment.

TABLE 24. Allowable Nutrient Loadings from Point Sources with Land Use Controls (Dillon Reservoir Only)

Element	Background Loading with Land Use Controls (lb/day)	Allowable Point Source Loadings (lb/day)
TKN	276 lb/day	477 lb/day
$NO_2 + NO_3$	56 lb/day	147 lb/day
Total Nitrogen	332 lb/day	624 lb/day
PO_4	110 lb/day	116 lb/day

VIII. EVALUATION OF ALTERNATIVES

A. Economic Evaluation

The alternative wastewater treatment plant layouts were prepared to see how consolidation of various drainage areas could be served in order to determine whether any one layout was more cost effective in meeting water quality objectives.

1. Process: Design Criteria and Data

Design criteria for the study were based on the following assumptions and estimates of population and sewage flows.

Table 25. Drainage Area Projected Populations and Sewage Flow

Drainage Basin	1977 Pop.	1977 ADF	1992 Pop.	1992 ADF
Upper Blue (Hoosier Pass to Lake Dillon)	20,000 @ 100 gpcd	2 mgd	75,000-103,000 @ 65 gpcd	4.9-6.7 mgd Use 6.0 mgd
10 Mile (Copper Mountain to Frisco)	12,000 @ 100 gpcd	1.2 mgd	25,000 @ 100 gpcd	2.5 mgd
Snake River (Montezuma to Summit Cove)	10,000 @ 100 gpcd	1.0 mgd	22,000 @ 90 gpcd	2.0 mgd
Dillon-Silverthorne (S. Side of Lake Dillon to Treatment Plant)	17,000 @ 100 gpd	1.7 mgd	40,000 @ 100 gpcd	4.0 mgd
Rock Creek (D-S Plant to R-C Plant)	1,000 @ 100 gpcd	1.0 mgd	10,000 @ 100 gpcd	1.0 mgd

TABLE 26. Criteria for Plant Design Efficiency

Estimated Raw Waste Strength mg/l		Sec. + P-Removal	
Parameter		Req. Removal[1] %	Effluent mg/l
BOD_5	200	98	4
S.S.	200	98	4
PO_4 as P	8	95	0.4
NO_3 as N	20	No Std.[2]	No Std.
Alkalinity	60	No Std.	No Std.

a) Wastewater

Estimated average strength was determined from raw sewage samples taken from existing treatment facilities in Summit County.

The alkalinity of the water was obtained from Denver Water Board samples in the Blue River Basin including Snake River, Ten Mile and the Upper Blue River.

b) Treatment Plant Design

The wastewater treatment plants were designed such that costs could be assigned to the various processes required. This meant that a cost for the entire secondary treatment process was estimated, including O&M costs and to that could be added the additional costs for phosphorus and nitrogen removal. The processes used for estimating purposes are

1. County standards were used in determining effluent criteria.
2. Nitrogen removal efficiencies used were 90% or 1.8 mg/l from effluent.

basically in use now, except for the nitrification-denitrification process which has not yet been operated on a full scale, continuous basis at a plant designed for nitrogen removal. All plants were designed for complete enclosure using pre-engineered buildings.

1) Secondary Treatment. The range of sizes of wastewater treatment plants estimated in this study eliminated the use of any one type of secondary treatment process. For small plant, 0.1 - 0.5 mgd, an extended aeration process with aerobic digestion of the waste activated sludge was chosen. Disposal on land or in landfills of the settled aerobically digested sludge was the method chosen for sludge disposal. The practice of disposing of this liquid digested sludge on the land would only be suitable for smaller treatment plants, larger facilities would have to thicken and dewater their sludge for disposal in sanitary landfills or for surface spreading on the land, possibly the Robinson tailings pond of the American Climax Corporation at Fremont Pass, or other suitable site.

For wastewater treatment plants in the 0.5 - 5.0 mgd range, the design was based on conventional activated sludge with aerobic digestion of the sludge, sludge dewatering by centrifuge, and disposal of the sludge in a landfill. A plant was also designed as a conventional activated sludge plant at 10 mgd but with primary

sedimentation and anaerobic digestion of all sludge, primary and secondary, with the dewatered sludge being disposed in a sanitary landfill.

Finally a 10 and 15 mgd plant was designed using a high rate activated sludge process again with primary sedimentation and anaerobic digestion of the sludge with ultimate sludge disposal being a sanitary landfill.

With the plant components derived from this plant sizing, the cost of each component was obtained from the EPA publication "Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities." The unit costs were not adjusted for 1972 costs in Denver since Denver costs run approximately 2 years behind national costs used in the publication. From these costs, a curve was plotted for plant capacity to compare with the wastewater treatment plant capital cost curve published by the JWPCF[1]. The projected costs for these plants was approximately 100% higher than the 1967 costs used on the WPCF chart. Our plotted cost curve was then used to determine capital costs for the various wastewater treatment plant sizes evaluated.

1. Journal, Water Pollution Control Federation, Vol. 40, No. 9, p. 1150, Fig. 6.

O&M costs for the plants were obtained by adjusting the O&M curve in the WPCF chart by the same percentage increase found for increased capital costs. The cost of sludge disposal is included in these O&M costs.

O&M costs were determined by determining the O&M cost/1000 gallons of sewage treated using the design capacity of the plant. The total O&M cost was then determined by using 80% of the design flow for actually treated flow. Hence a 1 mgd plant with an O&M cost of 10¢/1000 gal. would have a yearly O&M cost of:

$$\frac{(0.10)(1.0) \times (0.8) \times 365 \times 10^6}{10^3} = \$29,200$$

2) Phosphorus Removal. Since the waters have a low alkalinity, the best method of phosphorus removal appears to be the two-stage process.[1] This process will also enable the lime sludge to be recalcined best. The two-stage lime treatment process should also provide the best control for maintaining a low phosphorous effluent from the plant.

For the initial phase, there will be no plans for recalcining lime sludge waste from plants less than 2.5 mgd. For plants larger than 2.5 mgd recalcining of the lime will be provided for. In the future (1977 Construction),

1. U.S. Environmental Protection Agency, "Process Design Manual for Phosphorus Removal", p. 8, Oct. 1971.

all spent lime sludge could be taken to a single recalcining furnace to serve all separate wastewater treatment facilities. However, for this study this concept was not evaluated. Filtration of the two-stage clarifier effluent with mixed media filters would be next unless nitrogen removal process was added in which case the filters would follow the nitrogen removal. Costs for the phosphorus removal process and mixed media filtration were obtained by adjusting the 1967 cost figures developed by the Environmental Protection Agency.[1]

O&M costs for lime, lime sludge disposal and recalcination of lime were taken directly from the costs presented here, adjusted to 1972.

3) Nitrogen Removal. Nitrogen removal may be required and the removal system contemplated is nitrification of the effluent from the phosphorus removal process in a dispersed floc nitrification-denitrification process, using menthyl alcohol for denitrification.

Capital and O&M costs for the process were obtained from a preliminary copy of "The Cost of Dispersed Floc Nitrification and Denitrification for Removal of Nitrogen from Wastewater."[2]

1. U.S. Environmental Protection Agency, "Cost and Performance Estimates for Tertiary Wastewater Treating Processes, Report No. TWRC-9.
2. U.S. Environmental Protection Agency, "The Cost of Dispersed Floc Nitrification and Denitrification for Removal of nitrogen from Wastewater," Report.

4) Disinfection. Disinfection by chlorination of the effluent was provided whether or not denitrification was used. An advantage of nitrification or denitrification was the absence of ammonia which should greatly reduce the amount of chlorine required to disinfect the effluent or time of contact required and also eliminate potential toxic chloramines from being discharged. However, this chlorine reduction and/or contact time reduction was not used in determining chlorination costs.

2. Interceptor Design and Costs

A total of eleven different alternatives for collecting and treating the sewage from Rock Creek to Hoosier Pass were studied and costs estimated for construction and operation of the plants, interceptors and lift stations. The alternatives ranged from six individual plants to one regional plant at Rock Creek.

The following criteria were used in determining the sizing, operation and costs of various interceptor components.

a) Interceptors and force mains for transmitting raw or secondary sewage were designed for two times the ADF projected for the various drainage areas, except for low ADF when 2.5 ADF was used.

b) Where possible, interceptors and force mains were laid out near existing roadways, or where the Summit County Sewer Study had located interceptors.

c) Grades for interceptors were, if possible, determined from contours and road profiles, but where this data was not available, estimated grades were chosen for sizing or proposed grades from the Summit County Sewer Study were used.

d) Lift stations are sized for two ADF with one pump out. Standby power is provided. Lift stations are planned for replacement of pumps and standby power every ten years.

e) Most interceptors were designed for 1992 sewer flows while force mains were sized for initial flow only. Additional line capacity and lift station capacity added in a second phase (1977).

f) Interceptors and force main costs are based on a 6-8 foot burial depth.

g) For force mains, C = 130 using the Williams and Hazen formula.

h) Lift station and force main costs were assumed to be the same for pumping raw sewage or secondary effluent although secondary sewage pumping and lift station costs should be lower.

i) The construction of the force mains and lift stations is based on 1972 for Phase I, and 1977 for Phase II. Construction costs for 1977 are based on 1972 costs with no inflation.

TABLE 27. Interceptor and Lift Station Costs for Various Alternates[1]

	Capital Costs Millions of $		Operation & Maintenance Thousands of $	
	1972	1977	1972	1977
Alternative 2				
Dillon to Rock Creek	0.75			
Alternative 3				
Snake to Dillon	1.19		5000	
Alternative 4				
Snake to Dillon	1.19		5000	
Dillon to Rock Creek	.9			
Alternative 5				
Copper Mtn. to 10 Mile	0.5			
10 Mile - Dillon	0.803	0.232	20,000	40,000
Snake - Dillon	1.21		5,000	
	2.513	.232	25,000	40,000
Alternative 6				
Copper Mtn. - 10 Mile	0.5			
10 Mile - Dillon	0.803	0.232	20,000	40,000
Snake - Dillon	1.21		5,000	
Dillon - Rock Creek	1.2			
	3.713	.232	25,000	40,000
Alternative 7				
Copper Mtn. - 10 Mile	0.5			
Breckenridge - 10 Mile	0.656	0.986	46,000	93,000
10 Mile - Dillon	1.434	0.444	30,000	60,000
Snake - Dillon	1.21		5,000	
	2.800	1.430	81,000	153,000
Alternative 8				
Copper Mtn. - 10 Mile	0.5			
Breckenridge - 10 Mile	0.656	0.986	46,000	93,000
10 Mile - Dillon	1.434	0.444	30,000	60,000
Snake - Dillon	1.21		5,000	
Dillon - Rock Creek	1.5			
	4.3	1.43	81,000	153,000

(Continued)

1. See Appendix B for derivation of costs.

	Capital Costs Millions of $		Operation & Maintenance Thousands of $	
	1972	1977	1972	1977
Alternative 9				
Same as Alternative 7				
Alternative 10				
Same as Alternative 8				
Alternative 11				
Copper Mtn. - 10 Mile	0.5			
10 Mile - Dillon	0.803	0.232	20,000	40,000
Snake - Dillon	1.21		500	
	2.513	0.232	20,500	40,000

PW Factors

3.576 - 1977 O&M Costs
12.78 - 1973 O&M Costs
.7474- 1977 CC Costs

TABLE 28. Ten Mile Creek Drainage Interceptor Costs*
From Ten Mile Plant to Dillon-Silverthorne Plant

Interceptor Line	10 Mile Sewage Only		10 Mile & Breckenridge Sewage	
	Phase I	Phase II	Phase I	Phase II
Grav. to L.S. #1-18"	$96,000		192,000	
Grav. to L.S. #2 36"	70,000		140,000	
L.S. #1	80,000	80,000	120,000	150,000
Force Main #1-12"	60,000	60,000	100,000	120,000
L.S. #2	80,000	80,000	120,000	150,000
Force Main #2-12"	12,000	12,000	-20" 20,000	24" 24,000
I-70 to Buff. Mtn.	60,000		60,000	
Buff Mtn. to MHS-23	43,000		72,000	
MHS-23 to MHB-1	152,000		460,000	
MHB-1 to Plant	90,000		150,000	
1972	743,000	add.232,000	1,434,000	444,000
O&M	20,000	40,000	30,000	60,000

*Interceptor lift station and operating costs for transmitting raw sewage or secondary effluent were assumed to be nearly equal.

TABLE 29. Summary Lift Station and Interceptor Costs
Breckenridge to Ten Mile Creek

Phase I

10,800' of 15" forcemmain @ $20.00/Ft.	=	$216,000	
10,200' of 18" Gravity Line @ $20/Ft.	=	204,000	
4 mgd. L.S. - Raw Sewage (Peak Flow)	=	236,000	
TOTAL		$656,000	Initial Capital Cost
O&M Costs		$ 46,000	

Phase II - (Additional Costs)

10,800' of 20" Force Main @ 25.00/Ft.	=	$270,000	
7,200' of 24" Force Main @ $30.00/Ft.	=	216,000	
Add. 8 mgd capacity L.S.	=	500,000	
TOTAL		$986,000	Additional Capital Cost
Additional O&M Costs		$ 93,000	

TABLE 30. Summit County Alternative Wastewater Treatment Plant Cost Evaluation
Summary of Total Annual Cost and Capital Costs

Alternative and Investment Year	Flow	Secondary Removal C.C.	Secondary Removal TAC	Phosphorous Removal C.C.	Phosphorous Removal TAC		Secondary + Phos. Removal C.C.	Secondary + Phos. Removal TAC		Nitrogen Removal C.C.	Nitrogen Removal TAC	Sec. Phos. Removal + Nitrogen Removal T.C.C.	Sec. Phos. Removal + Nitrogen Removal TAC
#1	72	5.55	716,100	2.39	493,300	Low Initial C.C.	7.94	1,209,400		2.58	381,400	10.52	1,590,800
	77	5.30	665,700	2.9	544,500		8.20	1,210,200		1.96	356,400	10.16	1,566,600
	TOTAL	10.85	1,381,800	5.29	1,037,800		16.14	2,419,600		4.54	737,800	20.68	3,157,400
2	72	6.13	162,700	2.24	474,900		8.37	1,237,600		2.62	402,000	10.99	1,639,600
	77	4.85	612,900	2.30	446,000		7.15	1,058,900		1.48	317,400	18.63	1,376,300
	TOTAL	10.98	1,375,600	4.50	920,900		15.52	2,296,500		4.10	719,400	19.62	3,015,900
3	72	6.76	770,300	2.26	452,600		9.02	1,222,900		2.20	333,400	11.22	1,556,300
	77	5.00	629,100	2.41	480,700		7.41	1,109,800		1.84	352,800	9.25	1,462,600
	TOTAL	11.76	1,399,400	4.67	933,300		16.43	2,332,700		4.04	686,200	20.47	3,018,900
4	72	7.54	833,800	2.24	452,500		9.78	1,286,300		2.20	333,800	11.98	1,620,100
	77	4.50	572,600	2.13	406,100		6.63	978,700		1.44	397,600	8.07	1,376,300
	TOTAL	12.04	1,406,400	4.37	858,600		16.41	2,265,000		3.64	741,400	20.05	2,996,400
5	72	6.98	793,500	2.01	406,600		8.99	1,200,100		1.88	282,000	10.87	1,500,100
	77	4.43	612,400	1.99	414,700		6.42	1,027,100		1.94	300,000	8.36	1,327,100
	TOTAL	11.41	1,405,900	4.00	821,300		15.41	2,227,200		3.82	582,000	19.23	2,827,200
6	72	6.81	775,100	2.28	430,700		9.19	1,205,800		1.92	300,000	11.11	1,505,800
	77	4.28	578,600	1.48	331,500		5.76	910,100		1.38	281,000	7.14	1,191,100
	TOTAL	11.09	1,353,700	3.76	762,200	Low C.C.	14.95	2,115,900	Low TAC	3.30	581,000	18.25	2,696,900
7	72	6.47	782,100	1.57	319,600		8.04	1,101,700		1.36	212,000	9.40	1,313,700
	77	5.23	765,000	1.64	350,700		6.87	1,115,700		1.70	312,000	8.57	1,427,700
	TOTAL	11.70	1,547,100	3.21	670,300		14.91	2,217,400		3.06	524,000	17.97	2,741,400
8	72	7.80	894,400	1.63	326,100		9.43	1,220,500		1.34	240,000	10.77	1,460,500
	77	4.53	680,300	1.61	320,900		6.14	901,200		1.26	249,000	7.40	1,150,200
	TOTAL	12.33	1,574,700	3.24	647,000		15.57	2,221,700		2.60	489,000	18.17	2,610,700
9	72	8.35	716,100	1.57	644,700	*	9.92	1,360,800		1.36	212,000	11.28	1,572,800
	77	6.73	665,700	1.64	628,400	*	8.37	1,294,100		1.70	312,000	10.07	1,606,100
	TOTAL	15.08	1,381,800	3.21	1,273,100	*	18.29	2,654,900		3.06	524,000	21.35	3,178,900
10	72	9.85	716,100	1.63	782,000	*	11.48	1,498,100		1.34	240,000	12.82	1,738,100
	77	6.73	665,700	1.61	698,600	*	3.34	1,364,300		1.26	249,000	9.60	1,613,300
	TOTAL	15.58	1,381,800	3.24	1,480,600	*	19.82	2,862,400		2.60	489,000	22.42	3,351,400
11	72	8.01	716,100	2.04	650,900	*	10.05	1,367,000		1.76	281,000	11.81	1,648,000
	77	5.53	665,700	1.83	458,900	*	7.36	1,124,600		1.84	341,000	9.20	1,465,600
	TOTAL	13.54	1,381,800	3.89	1,109,800	*	17.41	2,491,600		3.60	622,000	21.01	3,113,600

*Includes cost of interceptors to take secondary effluent to tertiary plant.

CC = in millions of dollars
TAC = in dollars

The economics of non-point source control were not evaluated. However, it is likely that the economic impact of policies on land use controls to limit non-point sources of nutrients would be felt largely by developers who would experience higher construction costs for developing land and lower profits due to decreased residential densities in some areas susceptible to high nutrient production. It would seem, however, that such planning objectives as reducing nutrient production, could be tied to other objectives such as preserving open space, protection of flood plains and possibly population limitation objectives at some later date.

B. Environmental Assessment

The water quality control strategy which allows for the minimal impact on air, land, water and related resources may be a more desirable alternative even though its cost may be somewhat greater. The economic analysis has shown that none of the alternatives evaluated should be eliminated on the basis of cost. An environmental assessment of each of the alternatives was performed in order to select those alternatives that seemed to offer the smallest detrimental impact of any of the available alternatives.

Criteria for evaluating each of the alternatives involved impacts on the physical as well as cultural environments. Each of the criteria was weighted as follows:

TABLE 31. Impact Matrix Criteria and Relative Weights

Criteria	Relative Weight
(1) Water Quality Impact	4
(2) Reliability of Plant Operation	4
(3) Impact of Plant Failure	4
(4) Reliability of Transmission of Wastes	3
(5) Disruption During Construction	1
(6) Sludge Handling and Disposal	4
(7) Public Acceptance	1
(8) Disruption of Fish and Wildlife, Temporary	1
(9) Disruption of Fish and Wildlife, Permanent	3
(10) Site Locations: Social and Cultural Impact	2
(11) Site Locations: Aesthetics	3
(12) Loss of Resources: Land, Water, Nutrients, Recreation	3
(13) Water Law Compatiblity	3
(14) Growth Facilitation Potential	3
(15) Air Quality Impact	3
(16) Solid Waste Generated	3
(17) Flexibility of Plan	3
(18) Commitment of Resources	

The analysis of each alternative configuration for wastewater treatment plants seems to indicate that a subset of alternatives focusing on exportation of wastes out of the Dillon Reservoir watershed have a less detrimental impact on the physical and cultural environment of Summit County based on the above weighted criteria. These alternatives include:

1. Alternative 7. Secondary treatment, phosphorus removal, nitrification and denitrification of all wastewater generated in the basin at two regional plants: one at Dillon-Silverthorne and one at Rock Creek.
2. Alternative 8. Same as Alternative 7 with only one regional plant at the Rock Creek site.
3. Alternative 9. This alternative consists of secondary treatment plants located at Breckenridge, Snake River and Ten Mile Creek with all these secondary treated wastes transported to the Dillon-Silverthorne plant for phosphorous and nitrogen removal. The Rock Creek plant and Dillon-Silverthorne would provide integrated secondary and advanced treatment for wastes generated in the lower basin.
4. Alternative 10. Same as alternative 9 with advanced waste treatment provided at one plant at the Rock Creek site.

FIGURE 19. Impact Matrix for Water Quality Management Alternatives

Alternatives	Criteria Number	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	Rating
	(wt)	4	4	4	3	1	4	4	1	3	2	3	3	3	3	3	2	3	3	
		Water Quality Impact	Reliability of Operation	Impact of Plant Failure	Reliability of Transmission of Wastes	Disruption During Contact	Sludge Handling & Disposal	Public Acceptance	Disruption of Wildlife and Fishlife, Temporary	Disruption of Wildlife and Fishlife, Permanent	Site Locations-Social and Cultural	Site Locations-Aesthetics	Loss of Resources, Land Water, Nutrients, Recreation	Water Law Compatibility	Growth Filtration Potential	Air Quality Impact	Solid Waste Generated	Flexibility of Plan	Commitment of Resources	
Point Source Control:								Insufficient information to Evaluate at Present												
Alternative #1		-3	-2	-1	0	-1	-2	"	"	"	"	-3	+2	+3	-2	0	-1	-1	-2	-53
#2		-3	-1	-1	0	-1	-2	"	"	"	"	-3	-2	+3	-2	0	-1	-1	-2	-49
#3		-2	-1	-1	-1	-2	-2	"	"	"	"	-2	-1	0	-2	0	-1	-2	-2	-58
#4		-2	0	-1	-1	-2	-1	"	"	"	"	-2	-1	0	-2	0	-1	-2	-3	-53
#5		-1	0	-2	-2	-3	-1	"	"	"	"	-1	-1	-2	-2	0	-1	-1	-2	-54
#6		-1	+1	-3	-2	-3	+0	"	"	"	"	-1	-1	-2	-2	0	-1	-1	-1	-47
#7		0	+1	-3	-3	-3	+1	"	"	"	"	0	0	-3	-2	0	-1	0	0	-30
#8		0	+1	-3	-3	-3	+2	"	"	"	"	0	+1	-3	-2	0	-1	0	-2	-29
#9		0	+1	0	+1	-3	-1	"	"	"	"	-2	-2	-3	-2	0	-1	+1	-2	-31
#10		0	+1	0	+1	-3	-1	"	"	"	"	-2	-2	-3	-2	0	-1	+1	-3	-34
#11		-1	-1	-1	+1	-2	-1	"	"	"	"	-2	-2	-2	-2	0	-1	+1	-2	-43

	Beneficial Impact	Adverse Impact
0 = No adverse or beneficial Impact	+1 Small	-1
	+2 Moderate	-2
	+3 Large	-3

IX. MONITORING AND SURVEILLANCE NEEDS

In order to evaluate the effectiveness of the recommended water quality control strategy on a continuing basis, it is recommended that the level of effort for determining the water quality response due to the domestic and background waste loadings be increased.

A. Point Source Monitoring

Water quality from most municipal waste discharges in the Upper Blue River Basin is currently monitored by the Denver Water Board and the Colorado Water Pollution Control Division on a periodic basis. Selection of plants to be sampled intensively is based upon judgment of which plants constitute the highest potential for water quality degradation. The majority of this effort is directed at protecting the Dillon Reservoir watershed and at enforcing state effluent requirements for percent treatment levels for various constituents.

The Denver Water Board samples most of the water quality parameters at point sources which are of particular interest to water quality control in the Upper Blue River Basin. However, flow rates for point source discharges are not adequately defined for the basin as a whole. In order to develop more accurate knowledge of waste loadings, flow rates should be continuously measured for each major point discharge.

B. Non-Point Source Monitoring

Background water quality should be closely monitored at a point on all major tributaries which is not influenced by major point source discharges at various times throughout the year. Several small scale watershed sampling stations should be

established to determine the effect of increased construction activity on water quality. This could be accomplished by establishing stations on watersheds that are representative of undeveloped areas, rapidly developing areas, and established developments which have stabilized to some degree. Water quality parameters measured should specifically relate to nutrient loadings from suspended sediment in the bed load as well as conventional measurements. Particular emphasis should be placed on the Upper Blue River Basin where watershed changes are most dramatic. Effects of increased clearing of slopes for ski area development should likewise be monitored in order to adequately evaluate the direct environmental effects of ski area development in the watershed.

C. Ambient Water Quality Monitoring

In order to determine the effects of the known waste sources on ambient water quality, an increased effort will be necessary. Priority in this area should be placed on determining water quality parameters as a function of temperature stratification in the reservoirs and on determining the algal growth stimulation potential for various nutrient levels in the reservoirs.

Water quality as a function of depth and temperature should be determined for both reservoirs. Algal assays should be conducted to determine the growth stimulation for algae at various nutrient concentrations for environmental conditions which are known to exist in the reservoirs during the critical summer months.

X. SUMMARY AND RECOMMENDATIONS

A. Summary

1. Summit County, Colorado and the Blue River Hydrologic Basin are experiencing a period of dramatic growth in the demand for water and sewer services, generated primarily by the growth of several recreation oriented communities and developments. The water quality impact of the continued recreation development in the county is and will continue to be significant. Immediate plans for construction of wastewater treatment facilities to serve these developments call for an expansion from a total capacity of 5,000 population equivalent (P.E.) to a total design capacity of 52,370 P.E. for the Upper Blue River Basin alone. Long range projections (1985) indicate that the upper basin will ultimately require a total treatment plant design capacity of 105,000 P.E. A similar increase in demand for sewer services is projected for the lower Blue River Basin.

2. The projected growth in demand for sewer service will cause a dramatic rise in the concentration of nutrients within Dillon and Green Mountain Reservoirs, even with the assumption that all plants will meet the already stringent Summit County water quality standards for effluent discharges. Non-point sources, due to land use practices, construction activity, and leachate production from landfill, also contribute significantly to the nutrient loadings of both reservoirs. Background levels of nutrients in streams of the Upper Blue River Basin are approximately twice as high as is expected from an undisturbed watershed of similar character.

3. Increases in inorganic nitrogen concentrations from their current level of 0.035 mg/l - NO_3 to the projected level of 0.55 mg/l - NO_3 in Dillon Reservoir could be expected under the proposed level of development of treatment facilities alone. All guidelines indicate that this is an unacceptable increase in nutrient levels if a possible eutrophic condition in either of the reservoirs is to be averted.
4. Numerous alternative wastewater treatment plant configurations were evaluated on the basis of providing cost effective treatment tommeet the required objectives. It was determined that none of the alternatives studied could be eliminated on the basis of cost, since none of the costs varied more than the limits of accuracy.
5. As an alternative to wastewater treatment, land use controls were investigated. The levels of nutrient reductions which would be required if land use controls alone were relied upon to reach water quality objectives are beyond the level which would be expected to be produced by a virgin watershed. Land use controls alone are, therefore, not a viable alternative.
6. The impact of certain treatment plant configurations on the physical and cultural environment of Summit County seem to present a more desirable set of alternatives focusing largely on exportation of wastes from the Upper Blue River Basin either before treatment or after secondary treatment, with one or two regional advanced waste treatment facilities below Dillon Reservoir.

B. Recommendations

1. It is recommended that the current nutrient level in both reservoirs be maintained at their current level through appropriate treatment of point sources and control of non-point sources of nutrients. If it is assumed that background loadings can be maintained at or below their current levels, removal of 95% of the nitrogen from wastewater treatment plants will be required to achieve this objective.
2. It is recommended that additional effort be placed upon monitoring of discharges of pollutants and their resultant effects on water quality with particular emphasis on the two reservoirs. This will require additional monitoring of wastewater treatment plant effluents, ambient water quality in both reservoirs and streams, the algal growth stimulation effect of various nutrient levels, and monitoring of background nutrient levels produced due to land use practices.
3. It is recommended that this report be used as a framework for developing an interim water quality management plan that addressed itself to those projects needed to alleviate present problems.
4. It is recommended that a public meeting be conducted by the county to introduce this report and to discuss its findings and recommendations.
5. It is recommended that a more sophisticated water quality analysis plan be undertaken that considers needed institutional arrangements, financial capabilities and environmental impact of the various treatment alternatives.

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APPENDIX A. Dynamic Water Quality Simulator For Reservoirs

Appendix A. Dynamic Water Quality Simulator for Reservoirs

The goal of the model is to show the reservoir response to various input regimes using the concentrations of five substances to measure water quality. Of the substances modeled, three are conservative (T.K.N., nitrates and nitrites, phosphates) and two are non-conservative (B.O.D., D.O.). The basic model structure involves six water volume elements; three layers within the lake, discharge to the Lower Blue River, discharge thru the Roberts Tunnel, and inflow from Ten Mile Creek, Upper Blue River, and Snake River. Each volume element is tagged with five concentrations as noted above so that given an initial reservoir state and the inflow element on a monthly basis, the response of the other five elements to this inflow can be predicted across a monthly time span.

Processes within the lake used to determine the response are thermal stratification, interlayer mixing, evaporation, surface reaeration, and seasonal phenomenon (i.e. ice cover, fall and spring overturn, stream flow variations). Stratification is caused by sunlight heating the lake surface faster than the energy can dissipate downward which creates a surface layer lighter than lower waters, stream inflow during a stratified state will tend to follow the bottom of the lake until reaching waters having the same weight (i.e. density) as itself and then spread horizontally and mix with these waters. Some inter layer or vertical mixing will occur which will tend to even out vertical non-homogeneity in concentrations but the extent of this mixing is controlled by the strength of the stratification. Stratification will also occur in winter with colder water at the surface but it is much weaker than the summer stratification and can be considered as an almost

completely mixed state (i.e. vertically homogeneous). Overturns in spring and fall which lead to complete mixing are caused by the change in atmospheric conditions. These overturns occur in a relatively short period after which stratification develops slowly. At the surface, evaporation and restoration of an oxygen deficit will occur when ice cover is absent.

The discharge from wastewater treatment plants can be modeled as either discharging to the streams or directly to the lake. In the latter case, they will always contribute to the surface layer while in the former they will contribute to the layer that has the same density as the stream inflow.

The time unit used in the model is a month. This is fine enough to specify seasonal variables but not so fine as to require considering horizontal variations in concentrations, and it also makes the output more manageable over the 20 or 30 year study periods necessary for lakes.

INITIALIZATION PARAMETERS

1. Volumes and concentrations of the three layers
2. Decay and mixing constants
3. Background concentrations in streams
4. Evaporation in acre-feet per month
5. Concentration of nitrate if WWTP discharge is directly to the lake

MONTHLY INPUT

1. Inflow volume, concentrations, and temperature
2. Outflow volumes
3. Layer temperatures
4. Switch to specify overturn
5. Switch to specify ice cover presence
6. Interlayer mixing coefficients if wish to change
7. Month and year

MONTHLY OUTPUT

1. Volumes and concentrations of the three layers
2. Volumes and concentrations of the outflows

APPENDIX B

Derivation of Cost Data For Wastewater Treatment Alternatives

TEN MILE TO DILLON INTERCEPTORS

Ten Mile to Buffalo Mountain Subdivision

Plan 1 - 10 Mile Sewage Only

Phase I flow - 1.2 (Including C.M.)

Phase II flow - 2.5 (Including C.M.)

From 10 Mile Plant to Lift Station #1

Phase I ADF = 1.2 mg - 1.9 cfs - max. flow = 2 x 1.2 = 2.4 mgd = 3.7 cfs

Phase II ADF - 2.5 mgd - 3.8 cfs - max. DF = 2.x 2.5 = 5.0 mgd = 7.8 cfs

Put in 24" Concrete pipe. Takes care of Phase I and II.

4800 Lift of 24" Concrete pipe @ $20.00/Ft. = $96,000.

10 Mile Lift Station Design

Lift Station required. Install two lift stations -- one at Giberson Bay with force main to Heaton Bay Campground and another on Highway 9 to lift sewage up and under I-70 at Buffalo Park Subdivision.

Static head required.

Lift Station #1 - 9060 - 9010 = 50'

Lift Station #2 - 9100 - 9040 = 60'

TEN MILE SEWAGE ONLY - LIFT STATION #1 AND FORCE MAIN #1

Phase 1 - MDF = 2.4 mgd - 1700 gpm

12" force main - 4000' long.
at low flow = 0.5 mgd - 0400 gpm
at max. flow - 2.4 mgd - 1700 gpm
max. head req. - 50' x 4 x 6' - 74'
v = 1.2 fps head loss - 0.45'/1000'
v = 6.0 fps head loss = 6'/1000'

10" main
low flow (.5 mgd) 1.8 fps head loss = 1.0'/1000'
high flow (2.5 mgd) 6.5 fps head loss = 12.0'/1000'
max. head req. = 50' + 4 x 12 - 98'

Phase II - MDF - 5.0 mgd - 2.5 in Phase i L.S. - 2.5 mgd
2.5 mgd - 1700 gpm

Phase I - Use 12" force main with 2.5 mgd L.S. for 75' head.

Phase II - Add 12" force main with 2.5 mgd L.S. for 75' head.

L.S. #1 - 80,000 Phase I
80,000 Phase II

Force main 4000' of 12" C.I. @ 15.00/ft. = $60,000
$60,000 Phase II

L.S. # 2 and Force Main #2

Lift Station #2 and Force Main #2

L.S. #2 - Static Head = 60', Length = 800'

Phase I - peak flow - 2.5 mgd - 1700 gpm

Use same 12" force mains and L.S. as for L.S. #1.

Force main 800' long @ $15.00/ft. = $12,000.

Phase II - Similar units and costs.

GRAVITY LINE FROM FORCE MAIN #1 TO LIFT STATION #2

(1) 10 mile only - slope = 9060 - 9040 = 20'
distance = 3500'
slope = 20/3.5 = 5.5'/1000'
Use 5'/1000'

Phase I for 3.7 cfs flow - 15" pipe - required.

Phase II for 7.8 cfs flow - 18" pipe required.

Use 18" pipe, 3500' @ $ 20/ft. - $70,000.

Gravity Line - 10 Mile Interceptor

From S. side of I-70 to Junction with West end of Buffalo Mountain Subdivision MH, 1000' West of MHS-27

10 Mile Sewage Only

Slope - $\frac{200}{2400}$ = 80'/1000'

Use 20'/1000' for pipe sizing max. daily flow - 7.8 cfs

Use 15' pipe, 3300 lf 15" pipe @ $18/ft. = $60,000.

From Buffalo Mountain MHS-27 to MHS-23

10 Mile Only + (Silverthorne Sewage)

Phase I M.D.F. Flow - 3.7 cfs + 1.0 cfs (Buffalo Mtn., Cortina and Bayshore) = 4.7 cfs

Phase II M.D.F. Flow = 7.8 cfs + 2.0 cfs (Buffalo Mtn.,Cortina & Bayshore) = 9.8 cfs

Slope - $\frac{8920 - 8800}{2400}$ = 50'/1000'

Use 20'/1000' for design grade. Phase I* 2400' of 15" @ $18/ft. = $43,000.

Will handle Phase II additional flows also.

Blue River to Dillon-Silverthorne Plant MHS-23 to MHB-1

Phase I

Flow from 10 mile 3.7 cfs
from Silverthorne, B.M., M.C., & Cortine 1.0 cfs

Total 3.7 + 2 x 1.0 = 5.7 cfs
Vlt. = 7.8 + 2 x 1.5 - 10.8 cfs

Phase II

for pipe on 8'/1000' slope
required 18" concrete pipe

From Blue River to MH B-1 (MHS-23)

Length - 7600' - 18" pipe @ $20.00/ft = $152,000

MH B-1 to Dillon-Silverthorne Plant

Flow - 10 Mile, Dillon & Silverthorne only.

Flow

Phase I - 3.7 cfs (10 Mile) +(Dillon & Silverthorne) = 8.7 cfs
+ 2 x 1.7 mgd = 3.4 mgd = 5 cfs

Phase II - 7.8 cfs _ 2 (12 cfs) x 4.0 mgd) = 20 cfs

Slope - 4'/1000' Length - 3000'

Use 24" pipe @ $30.00/ft. - $90,000

10 Mile + Breckenridge to Dillon Silverthorne Plant

Gravity Line to carry 10 mile + Breckenridge wastes to L.S. #1.

Phase I: ADF - 1.2 + 2.0 (Breckenridge) - 3.2 mgd

MDF - 2.0 x 3.2 = 6.4 mgd - 10 cfs

Phase II: ADF - (2.5 + 6.0) - 8.5 mgd

MDF - 2.0 x 8.5 - 17.0 mgd - 27 cfs

Gravity Pipe for Phase I

10 cfs flow - Reqires 24" pipe

Phase II - 27 cfs total

Requires 36" pipe total or an additional 27 cfs - 10 cfs = 17 cfs, 30 inch pipe.

Install 36" pipe immediately to provide for Phase I and II.

4800 L.F. of 36" Conc. pipe @ $40/ft. - $19,200

L.S. #1 and Forcemain

Phase I: Max. flow - 3.2 x 2.0 = 6.4 mgd - 4,500 gpm

Phase II: Max. flow - 8.5 x 2.0 - 17.0 mgd - 12,000 gpm

Static head - 50'

Phase I - 4,500 gpm - 18" pipe has 5' head loss/1000'

20" pipe has 3' head loss/1000'

Total head req. = 50' + 3(4) = 62'

Phase II add. capac. req. 12,000-4,500 - 7,500 gpm
24" pipe - 3' headloss/1000'
20" pipe - 7.9' headloss/1000'

Phase I: Use 20" pipe initially of 4000' @ $25.00/ft. = 100,000

Phase II: Add 24" pipe in Phase II 4000' @ 30.00/ft. = $120,000

Head required - 50' + 0.8/3' = 52.5'

L.S. #1 - $120,000 = Phase I
$150,000 = Phase II

L.S. #2: Use same design and costs as for L.S. #1

120,000 Phase I
150,000 Phase II

Force Main #2: Same size as for force main #1

Phase I: 800' of 20" @ $25.00/Ft. - $20,000

Phase II: 800' of 24" @ $30.00/Ft. = $24,000

Gravity Line from Forece Main #1 to L.S. #2

(2) 10 Mile and Breckenridge

Phase I: for 10 cfs - 21" pipe

Phase II: for 27 cfs - 30" pipe

Use 30" pipe

Require 3,500' of 30" pipe @ $40/Ft. - $140,000

<u>10 Mile Interceptor + Breckenridge</u>

I-70 to Buffalo Mtn., (1000' West of MHS-23) 15" - 3300 LF @ $18/Ft. = $60,000

Buffalo Mtn. to MH S-23

Use 1992 loads for sizing interceptor

Flow - 27 cfs + 1.0 = 28 cfs

Slope - 20'/1000'

Use 24" pipe

30" 2400 LF @ $30/Ft. = $72,000

MH S-23 to MH B-1

Slope - 8'/1000'

Flow = 28 cfs + Silverthorne (2 x 1.5 cfs)
- 31 cfs

Use 30" pipe - 7,600 L.F. @ $35/Ft. = $460,000

Use 1992 loads for sizing interceptors.

MH B-1 to Plant

Flow - 27 cfs + $\frac{12 \text{ cfs}}{(4 \text{ mgd} \times 2)}$ = 39 cfs

Slope - 4'/1000'

Use 36" - 3000' @ $50.00/Ft. = $150,000

SNAKE CREEK INTERCEPTOR

Pipe Sizing from Summit County Sewer Study from plant (MH D-132) to MH D-70)

24" - 23,900 L.F. = $913,000

From MH D-1 to MH D-35 (to MH. B-1)

30" - 4,000' @ $35.00/Ft. = $140,000

Phase I & Phase II Lift Station + Force Main - Summit Cove to Interceptor--$50,000

Cost of Line from MH B-1 to Plant MH B-1 to Dillon Plant

a) Dillon & Silverthorne & Snake River

Flow - 6.0 mgd x 2 - 12 mgd - 17 cfs

Slope - 4'/1000'

Use 24" pipe - 8000' of 24" [$30.00/Ft. = $90,000

b) Dillon, Silverthorne, Snake and 10 Mile

Flow - (2.5 + 6.0) x 2 = 17 mgd - 27 cfs

Slope = 4'/1000'

Use 30" pipe - 3000' of 30" [$35.00/Ft. - $105,000

c) Dillon-Silverthorne, Snake, 10 Mile & Breckenridge

Flow = 27 cfs + 17 - 42 cfs

Slope - 4'/1000'

Use 36" pipe - 3000' @ $50.00/Ft. = $150,000

DILLON TO R.C. INTERCEPTOR
B-17 to B-112

Distance = (4' - 2-1/2") - 40-1/2" x 600' 1/IN = 30,000 Ft.

a) Dillon & Silverthorne only = 4.0 x 2.0 = 8 mgd - 7.5 cfs

Use 24"
30,000 LF @ $25/Ft. = $750,000

b) Dillon & Silverthorne & Snake (8 + 2 x 2.0) = 12 mgd.

30" - 30,000' @ $30.00/Ft. = $900,000

c) Dillon-Silverthorne, Snake & 10 Mile = (12 + 2 x 2.5) = 17 mgd

33" - 30,000' @ $40/Ft. = $1,200,000

d) Dillon-Silverthorne, Snake, 10 Mile & Breckenridge = (17 + 2 x 6) = 29 mgd

36" - 30,000' @ 50'/Ft. = $1,500,000

INTERCEPTOR COSTS

I. Copper Mountain Line - From Copper Mountain to 10 Mile Creek Plant Site

Length - 6.4 miles x 5,280' = 33,700 L.F.

Difference in elevation = 9,700 to 9,020 = 680'

Slope = 680/33,700 = 0.0202 - 20.2/1000'

1992 ADF = 0.5 mgd

Deisgn Interceptor for 2.5 x ADF = 1.25 mgd - 1.25 mgd = 1.94 cfs

8" pipe @ 20'/1000' has capacity of 1.75 cfs flowing full @ n value of 0.012

Design for s = 10'/1000' - Req. 8" line

Unit cost of pipe buried @ 8' depth including excavation and manhold costs = $15/ft.

Cost: 33,700 ft. x $15/ft. = $505,000

II. Breckenridge to Ten Mile - L.S. and Interceptor Design and Costs

A. Lift Station and force main from Breckenridge plant to top of hill.

Pump Station Req.

Bottom Elevation of Filters - elevation - 9034; Bottom elevation of chlor. - 9030

Make bottom elevation of lift station 20' below filter floor

Use elev. 9015

Force main - bury at 8' depth to prevent freezing on downhill side of St. Hiway 9. Force main to end at top of hill.

Gravity sewer to 10 mile plant site.

Head Req. - Top of Hill elev. 9130

Bottom of wet well 9015

Static head 115'

Pump Capacity

Provide pumps and force main for 2 x ADF Req. 4 mgd pump capacity with largest unit out of service.

For maximum head loss - figure on 4 mgd flow

@ 4 mgd = 2,800 gpm flow

@ 2 mgd = 1,400 gpm flow

@ Ult. capacity, 6.0 mgd flow

@ Ult. capacity - peak flow 12.0 mgd flow

Additional Req. capacity 6-2 = 4 mgd design = 2,800 gpm

12-4 = 8 mgd max. ult. daily flow = 5,600 gpm

@ 2,800 gpm flow, and 20" pipe size - 1.4'/1000' @ 3.0 fps

@ 5,600 gpm flow, and 20" pipe size - 4.5'/1000' @ 5.8 fps

@ 2,800 gpm flow, and 24" pipe size - 0.6/1000' @ 2.2 fps

@ 5,600 gpm flow, and 24" pipe size - 2.0'/1000' @ 4.2 fps

For Design

1st Stage pipe size - 15"

2nd stage pipe size - 20"

@ 4 mgd 18" pipe size, Head loss = 1.5'/1000' @ 2.8 fps rel.

@ 8 mgd 18" pipe size, Head loss = 7.0'/1000' @ 7.0 fps rel.

@ 4 mgd 12" pipe size, Head loss = 13'/1000' @ 7.5 fps rel.

@ 4 mgd 15" pipe size, Head loss = 5'/1000' @ 5.0 fps rel.

@ 2 mgd 15" pipe size, Head loss = 1.5'/1000' @ 2.6 fps rel.

Put in initially 15" C.I. force main, because at low flows, solids may settle out in the long force main an additional 6" force main may be required for use at low flows during low flow seasons.

Length of pipe required - 10,800 ft.

@ 2 mgd ADF Cost of 15" C.I. pipe = 10,800 ft. @ 27.00/Ft. = 216,000

@ 6 mgd ADF Cost of 20" C.I. pipe = 10,800 ft. @ $25.00/Ft* = $270,000

Gravity Sewer Line Design from Force Main at Top of Hill to 10 Mile Creek Plant

Length - 10,200 ft., but since grade breaks, pipe can be sized for different grades.

Grade - 3000' @ 20'/1000'

7200' @ 3'/1000'

For 2 mgd flow (3.1 cfs) x 2.0 = 6.2 cfs design

6 mgd flow (9.3 cfs) x 2.0 = 18.4 cfs

2 mgd flow - 3000' length - required 12" - Capacity of 10 cfs

2 mgd flow - 7200' length - required 18" pipe - capacity of 6 cfs

6 mgd flow (18.4 cfs) 3000' length - required 18" pipe - This pipe will be sufficient to carry 1990 flows.

6 mgd flow (18.4 cfs) 7,200' length - required 30" pipe or put in 2nd pipe for 18.4 - 6.0 - 12.4 cfs, 7200' = required 24" pipe.

COST OF GRAVITY LINE FROM TOP OF HILL TO 10 MILE PLANT

Gravity Lines

Phase I: Put in 3000' of 18" pipe @ 20'/1000' slope @ $20/Ft. = $60,000

(This will be adequate for 1992 flows.)

Put in 7,200' of 18" pipe @ 3'/1000' slope @ 20/Ft. - $144,000

Phase II: Put in 7,200' of 24" pipe @ 3'/1000' slope @ $30/Ft. = $216,000.

Lift Station Design and Costs

Phase I: Head Req. = 115' static.

Design Flow: 2-4 mgd

15" pipe friction head - 2 mgd - 1.5 x 10.8 = 16' TDH - 131'

4 mgd - 5.0 x 10.8 = 54' TDH - 169'

Phase II: First phase pumps have 4 mgd capacity

Req. 12-4 - 8 mgd capacity at maximum flow

Design Flow: 6-12 mgd

Friction Head 8 mgd - 5.8 x 10.8 = 63' TDH - 178' in 20" pipe.

Breckenridge L.S. Costs--Raw Sewage L.S.

For Phase I - 2 mgd average flow, 4 mgd peak flow

Contractor Cost	Use 3-2 mgd pumps (variable speed) for 170' head Pump, motors, controls, etc. (125 HP motors)	$57,000
	Generator (350 kw)	37,000
	Package station (valves, wiring, building, etc.)	75,000
		$169,000
	Contractor Add on - 0.4 x 169,000 =	67,600
	Total Cost	$236,600
	Excavation, wet well, and installation =	25,000
	TOTAL LIFT STATION COST =	$251,000

O&M Cost/Year

10 year mechanical life of pumps, etc.	94,000 ÷ 10 =	$9,400
5% of initial cost of machines for repair	5% x 94,000=	4,700
Routine Maintenance - 5% of total cost		12,500
Elect. - $70/Day (for 2 mgd) x 0.8 x 365		= 20,200
(Based on 2¢/kw hr. cost) O&M		=/46,800/

For Phase II - (Use twice initial lift station cost)

Additional Costs

Capital Costs	= $500,000
O&M	= 93,000